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# LRFD Guide Specifications for the Design of FRP Pedestrian Bridges



2<sup>ND</sup>  
EDITION



AASHTO

American Association of State Highway  
and Transportation Officials

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# INTRODUCTION

## 1.1—SCOPE

These Guide Specifications apply to bridges and other structures constructed with fiber-reinforced polymer (FRP) composite members or FRP decking. These structures are designed to carry primarily pedestrians, bicyclists, equestrian riders, and light maintenance vehicles, but not highway traffic. FRP pedestrian bridges covered by these Guide Specifications include truss bridges constructed with pultruded FRP members, pultruded FRP decking, and FRP members manufactured using a vacuum infusion process (VIP).

These Guide Specifications provide additional guidance as a supplement to the *AASHTO LRFD Bridge Design Specifications* (AASHTO BDS) and the *AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges*, 2nd Edition (AASHTO PEDESTRIAN) (AASHTO, 2024) (AASHTO, 2015). Only those issues unique to the design of FRP pedestrian bridges are addressed in these Guide Specifications.

These Guide Specifications refer to ASCE/SEI 7-22 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7) for loadings important to FRP pedestrian bridges that are not adequately addressed in AASHTO BDS or in AASHTO PEDESTRIAN.

## C1.1

The first edition of these Guide Specifications (2008) was intended for truss-style pedestrian bridges constructed with pultruded FRP structural shapes. Since 2008, pultruded FRP planks and VIP-molded FRP panels have been used as bridge decking in numerous bridge projects. FRP beams have been used to support decks of pedestrian bridges. Long span VIP-molded FRP double-tees and triple-tees have been used in commuter rail platforms. The provisions contained in these Guide Specifications may also be applicable to other structures, such as sidewalks cantilevered off existing bridges, commuter rail platforms, and boardwalks.

These Guide Specifications include provisions for the design and detailing of pultruded FRP structural shapes used in the construction of truss bridges and FRP decking supported on steel, reinforced concrete, or FRP beams. FRP decking includes pultruded FRP planks and VIP-molded FRP sandwich panels.

Timber planks are often used as decking on FRP truss bridges. Design guidelines for timber decking are covered by other references, including *National Design Specification (NDS) for Wood Construction*.

Representative examples of FRP pedestrian bridge projects are shown in Figures C1.1-1 through C1.1-6.

This first edition of these Guide Specifications was based on Allowable Stress Design (ASD) and Load Factor Design (LFD). This edition is based on AASHTO BDS and integrates current state of practice for the design and detailing of FRP composite pedestrian bridges.

Loadings important to FRP pedestrian bridges, such as snow loading, are better addressed in ASCE 7.

These Guide Specifications refer to the interim material specification in Appendix D until requirements are added to AASHTO M 337 or another AASHTO material specification for FRP pedestrian bridges is published.

These Guide Specifications incorporate information and guidelines from other FRP standards and technical specifications, including ASCE/SEI 74 *Load and Resistance Factor Design (LRFD) for Pultruded Fiber Reinforced Polymer (FRP) Structures* (ASCE 74) and the JRC Report EUR 27666 EN, *Prospect for New Guidance in the Design of FRP* (EURO GUIDE), which is the basis for the technical specifications for FRP structures published by many European countries (Ascione et al., 2016).

For ease of use, some information found in the reference documents is replicated in these Guide Specifications.

In these Guide Specifications, the term “FRP Pedestrian Bridge” shall mean any pedestrian bridge whose superstructure or deck is constructed with FRP members. FRP truss bridges with timber decks are also classified as FRP pedestrian bridges.

AASHTO M 337 defines the requirements for FRP strengthening systems and is not entirely suitable for the FRP materials used in FRP pedestrian bridges.

ASCE 74 represents the current state of practice for the LRFD design of pultruded FRP structures. EURO GUIDE is wider in scope than ASCE 74, including provisions for VIP-molded panels.



**Figure C1.1-1—Flatt's Inlet FRP Pedestrian Truss Bridge (Bermuda)**  
(Source: Creative Composites Group)



**Figure C1.1-2—VIP-Molded FRP Panels Used on Suspension Pedestrian Bridge (Trail, British Columbia, Canada) (Source: Graham Group)**



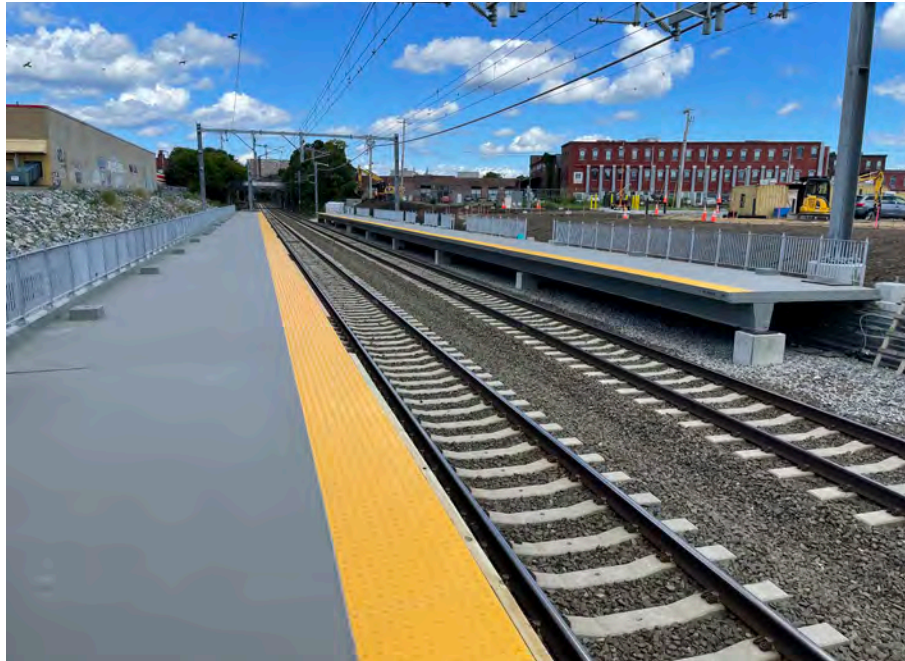
**Figure C1.1-3—VIP-Molded FRP Deck Panels Used on Rail Crossing Pedestrian Bridge (Boston, MA) (Source: Creative Composites Group)**



**Figure C1.1-4—Pultruded FRP Planks Used in Construction of Cantilevered Sidewalk (Clinton Township, MI) (Source: C.A. Hull Company)**



**Figure C1.1-5—VIP-Molded FRP Panels Used in Construction of Cantilevered Sidewalk (Arlington, WA) (Source: Francis Zera Photography)**



**Figure C1.1-6—VIP-Molded FRP Tee Panels Used in Construction of Rail Platform (Pawtucket, RI)** (Source: Coastline Composites)

## 1.2—DEFINITIONS

*Additives*—Substances added to the polymer resin to improve properties or aid in the processing of the FRP composite material.

*Adhesive*—Substance capable of holding materials together by surface bond, through chemical or mechanical bond.

*Anisotropic*—Exhibiting properties with different values when measured along axes in different directions.

*Balanced Laminate*—A composite in which all laminae at angles other than 0 and 90 degrees occur in +/- pairs with the pairs having the same thickness and material (not necessarily adjacent).

*Carbon Fiber*—A reinforcing fiber known for its light weight, high strength, and high stiffness produced by pyrolysis of an organic precursor fiber in an inert atmosphere at temperatures above 1800°F. Can also be graphitized by heat treating above 3,000°F.

*CFRP*—Carbon fiber-reinforced polymer.

*Characteristic Design Value*—Statistically-based property value representing the 80 percent lower confidence bound on the fifth-percentile value of a specified population, determined in accordance with ASTM D7290.

*Chopped Strand Mats*—Continuous strand yarn or roving cut up into uniform lengths, usually from 1 to 2 in. long, and pressed flat to form fabric held together with a binder.

*Classical Lamination Theory (CLT)*—A theoretical framework used in the field of mechanics of composite materials. It provides a methodology to analyze the complex mechanical behavior of composite structures

consisting of layers, or laminae, of different materials bonded together to form a stronger and more versatile material. CLT is used to predict laminate properties such as stiffness, strength, and thermal behavior.

*Continuous Strand Mats*—Continuous strand yarn or roving randomly swirled and pressed flat to form fabric held together with a binder.

*Core*—The central component to which inner and outer face skins are attached.

*E-Glass*—A family of glasses with a calcium aluminoborosilicate composition and a maximum alkali content of two percent; a general-purpose fiber that is most often used in reinforced plastics and is suitable for electrical laminates because of its high resistivity.

*Engineer*—Person responsible for the design of the bridge or review of design-related submittals such as the FRP bridge shop drawings.

*Fabric, Non-Woven*—A material formed from fibers or yarns without interlacing.

*Fabric, Woven*—A material constructed of interlaced yarns or fibers.

*Fiber-Reinforced Polymer (FRP)*—A general term for a composite material comprising a polymer matrix reinforced with fibers in the form of fabric, mat, and strands.

*Fiber Volume Fraction*—Volume of reinforcement fiber in a cured FRP composite laminate section divided by the volume of the section.

*Fiber*—A general term used to refer to filamentary materials; a filament with a finite length that is at least 100 times its diameter, which is typically 0.004 to 0.005 in. In most cases it is prepared by drawing from a molten bath, spinning, or deposition on a substrate. Fibers can be continuous or specific short lengths, normally less than 0.125 inch.

*Filament Winding*—A process that involves winding a resin-saturated strand of glass filament around a rotating mandrel.

*FRP Deck*—Pultruded FRP planks and VIP-molded FRP panels used as bridge decking.

*FRP Engineer*—Person responsible for the preparation of design calculations and shop drawings of an FRP bridge. Usually, a consultant to or employee of the FRP manufacturer.

*FRP Manufacturer*—See Manufacturer.

*FRP Pedestrian Bridge*—Any pedestrian bridge whose superstructure or deck is constructed with FRP members.

*FRP Plank*—A pultruded FRP structural shape with an open or closed bottom, often used for applications such as as bridge decking.

*FRP Sandwich Panel*—A structure made of three layers: a low-density closed-cell core material, and a thin skin-layer adhered to each side.

*GFRP*—Glass fiber-reinforced polymer.

*Glass Transition Temperature ( $T_g$ )*—Temperature at which the polymer matrix changes from a vitreous state to a rubbery state, as determined by dynamic mechanical analysis performed in accordance with ASTM E1640 at the mid point of the temperature range over which this change of state occurs.

*Hand Layup*—A fabrication method in which reinforcement layers, pre-impregnated or coated afterward, are placed in a mold by hand and then cured to the formed shape.

*Lamina*—A single layer of FRP composite material. A lamina may consist of unidirectional fiber rovings, multi-directional fiber fabrics, or mats. Also known as ply.

*Laminate*—An FRP composite constructed by stacking up lamina oriented in various directions to achieve desired properties and thickness. Laminates are used to create the FRP members and structures used in bridges.

*Manufacturer*—Company responsible for fabricating the FRP components, planks, and deck panels used in the construction of the FRP pedestrian bridge.

*Owner*—Person or agency having jurisdiction over the bridge.

*PET*—Polyethylene terephthalate.

*Polyester*—A class of thermosetting resins containing dibasic organic acid and polyhydric alcohols.

*Polymer*—A resin where large molecules are formed by combining many smaller molecules or monomers in a regular pattern.

*Pultrusion*—A continuous process for manufacturing composites that have a constant cross-sectional shape. The process consists of pulling a fiber-reinforcing material through a resin impregnation bath and through a shaping die, where the resin is subsequently cured.

*PVC*—Polyvinyl chloride.

*Quasi-Isotropic Laminate*—An FRP laminate having near isotropic properties in-plane.

*Rovings*—A long and narrow bundle of fibers.

*Symmetric Laminate*—An FRP laminate in which the type, angle, and thickness of the layers are the same above and below the midplane.

*Vacuum Infusion Molding*—A composite manufacturing process and molding technique that uses vacuum pressure to drive resin into a laminate or FRP sandwich panel under a vacuum bag.

*Vacuum Infusion Process (VIP)*—Generic composite manufacturing process term to include any infusion process that uses vacuum as the sole force to saturate a fiber preform or FRP sandwich panel.

*VARTM*—Vacuum-assisted resin transfer molding. See Vacuum Infusion Process.

*Vinyl Ester*—A class of thermosetting resins containing ester of acrylic or methacrylic acids, many of which have been made from epoxy resin.

### 1.3—NOTATION

- $C_D$  = Drag coefficient (C3.9)  
 $C_E$  = Environmental adjustment factor (4.4.2)  
 $C_L$  = Lateral drag coefficient (C3.9)  
 $C_T$  = Temperature adjustment factor (4.4.3)  
 $R_n$  = Nominal design strength (6.2)  
 $R_u$  = Factored applied loading (6.2)  
 $X_0$  = Characteristic stress, strain, modulus, or mean modulus (4.4)  
 $X_n$  = Design strength, strain, or modulus (4.4)  
 $T$  = Maximum ambient temperature (4.4.3)  
 $T_g$  = Glass transition temperature (4.5)  
 $\phi$  = Resistance factor (6.4)  
 $\lambda$  = Time effect factor (6.5)

### 1.4—AXES ORIENTATION CONVENTION

The axes of orientation for the FRP pedestrian bridge, FRP members, and FRP laminates used in these Guide Specifications are described below:

Bridge:

- Longitudinal—Direction parallel to the span of the bridge.
- Transverse—Direction orthogonal to the longitudinal direction of the span.

Bridge Decking:

- Longitudinal—Direction parallel to the span of the decking.
- Transverse—Direction orthogonal to the longitudinal direction of the span of the decking.

Pultruded FRP Members:

- Lengthwise (Longitudinal)—Direction parallel to the span of the member or the primary load carrying direction of the member.
- Crosswise (Transverse)—Direction orthogonal to the lengthwise direction.

### C1.4

Defining the sign convention and bridge or member axis is important with FRP materials since they are anisotropic.

The axes of an FRP pedestrian bridge are the same as any traditional bridge. The longitudinal direction is usually the direction pedestrians or vehicles move over the bridge.

Bridge decking is typically supported by stringers aligned in the longitudinal direction of the bridge or on floor beams aligned in the transverse direction of the bridge. The longitudinal axis of FRP decking can be the same direction as the longitudinal direction of the bridge when the decking is supported on floor beams.

Typical pultruded profiles include I-beams, channels, angles, tubes, and planks, where the lengthwise direction is in the same direction as the length of those profiles. The lengthwise direction of pultruded profiles will usually have a higher percentage of fibers aligned in that direction.

**VIP-Molded FRP Members:**

- Longitudinal (0 degree–direction)—Direction parallel to the span of the member or the primary load carrying direction of the member.
- Transverse (90 degree–direction)—Direction orthogonal to the longitudinal direction of the span of the member.

**FRP Plates, Panels, or Laminates:**

- 0 degree—direction of the primary loading for in-plane loading or primary bending direction.
- 90 degree—direction perpendicular to the primary in-plane loading or bending.

**1.5—DESIGN PHILOSOPHY**

FRP pedestrian bridges shall be designed for specified limit states to achieve the objectives of safety, strength, serviceability, and constructability with due regard to issues of inspectability, maintainability, economy, and aesthetics as specified in AASHTO BDS (AASHTO, 2024). These Guide Specifications are based on the LRFD philosophy.

VIP-molded FRP members can have large planar dimensions. Most VIP-molded FRP panels are designed as one-way slabs. The direction of the span is considered the longitudinal direction and is the same direction as the primary load carrying webs. In the case of FRP double-tee members, the longitudinal direction is the direction the double-tee spans. The flange portion of the double-tee spans transversely between the stems and is designed as a one-way slab.

FRP laminates and plates utilize an angle designation to define the axes. FRP composite laminates are made by stacking up lamina aligned at various angles through the thickness. The 0 degree direction represents the primary load-carrying direction and usually has the highest percentage of fibers aligned in that direction.

**C1.5**

A 75-year design life for FRP pedestrian bridges should be used for consistency with AASHTO BDS. FRP pedestrian bridges have historically been designed using an ASD approach to achieve factors of safety between 3 and 5. In cases where there was insufficient information for calibration using reliability theory, values of resistance factors were chosen based on judgment, so that the design using LRFD procedures was consistent with that which used the ASD procedures that have produced well-performing bridges over the last 30 years.

Mixing provisions other than those referenced herein, even if LRFD is used, should be avoided.

Failures of a few bridges have been attributed to poor detailing or underestimating loads, particularly sustained snow loads.

FRP materials have a lower modulus than steel; therefore FRP decking designs are almost always controlled by the deflection requirements, leading to a high reserve of strength. FRP pedestrian truss bridge designs may be controlled by the compression strength of the top chord, stability of the top chord, deflection, or vibration.

These Guide Specifications emphasize a delegated design approach where the manufacturer is responsible for the design of the FRP pedestrian bridge using performance specifications and requirements specified by the Designer/Owner.

## 1.6—FRP MANUFACTURER-DESIGNED PEDESTRIAN BRIDGES

When an FRP-manufacturer-designed FRP pedestrian bridge is used, the Engineer responsible for the design of the FRP bridge or the FRP members shall submit sealed calculations prepared by a licensed Professional Engineer for the FRP members. The Engineer responsible for the design of the FRP bridge or FRP members shall be experienced with the design of such members.

## 1.7—ACCEPTABLE FRP TYPES

Pultruded FRP members or VIP-molded FRP panels shall be considered acceptable FRP types for pedestrian bridge projects.

### C1.6

Most FRP pedestrian bridge projects are designed by the FRP manufacturer or their FRP Engineer to comply with the performance requirements specified by the Owner or their Engineer. The Designer should check local regulations and the specifications for requirements regarding licensure in the jurisdiction where the project will be constructed.

It is important to clearly delineate the responsibilities of each party when proprietary bridges or proprietary bridge products are used. All portions of the design must be supported by sealed calculations, whether from the FRP manufacturer or the specifying Engineer. A delegated design approach is typically used for FRP pedestrian bridges where the FRP manufacturer is responsible for the design of their products and systems.

### C1.7

These Guide Specifications are based on the experiences of FRP pedestrian bridges constructed with pultruded FRP members and VIP-molded FRP panels made using E-glass fibers and vinyl ester or isophthalic polyester resins. Nearly all FRP pedestrian bridges constructed since the early 2000s have used pultruded FRP members or VIP-molded FRP sandwich panels. The compilation of lessons learned from these FRP pedestrian bridge projects represents the current state of practice and is reflected in these Guide Specifications. FRP pedestrian bridges constructed with other materials or manufactured using methods other than pultrusion or VIP molding lack comparable experience and case histories. While potentially suitable for use, rigorous testing is required to ensure compliance with the requirements of these Guide Specifications.

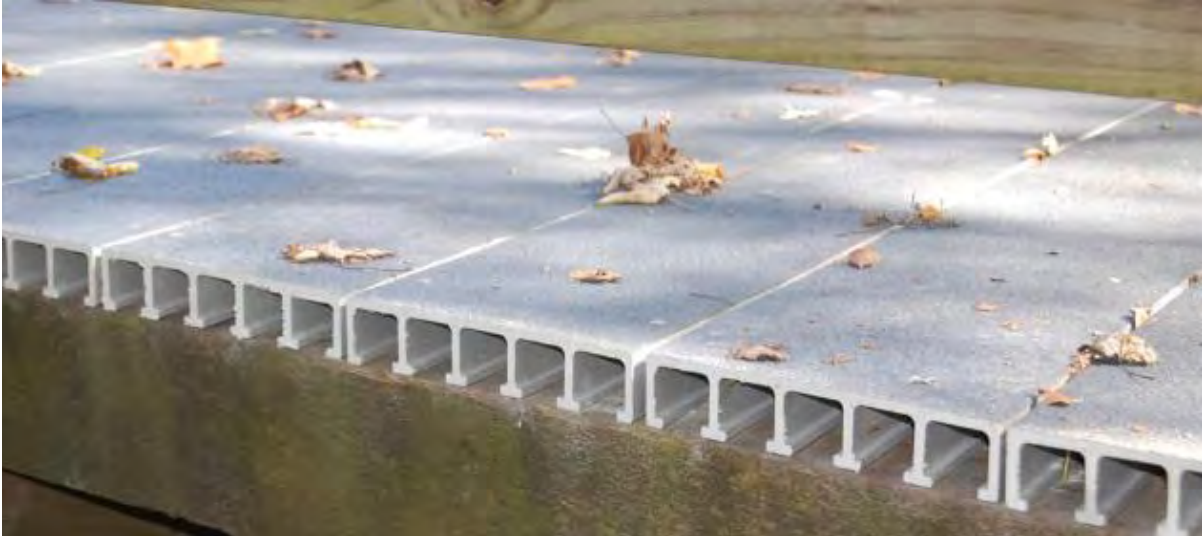
Pultrusion and VIP molding are two of several composite manufacturing processes used to combine the reinforcing fibers and polymer resins to create an FRP member or structure. Both processes result in FRP laminates with high fiber volume fraction (>40 percent), high mechanical properties, and superior durability.

Pultruded members include structural profiles like I-beams, channels, angles, hollow tubes, bars, plates, and various deck planking profiles. A pultruded FRP plank is shown in Figure C1.7-1. VIP molding is used to produce FRP sandwich panels consisting of FRP face skins and FRP webs

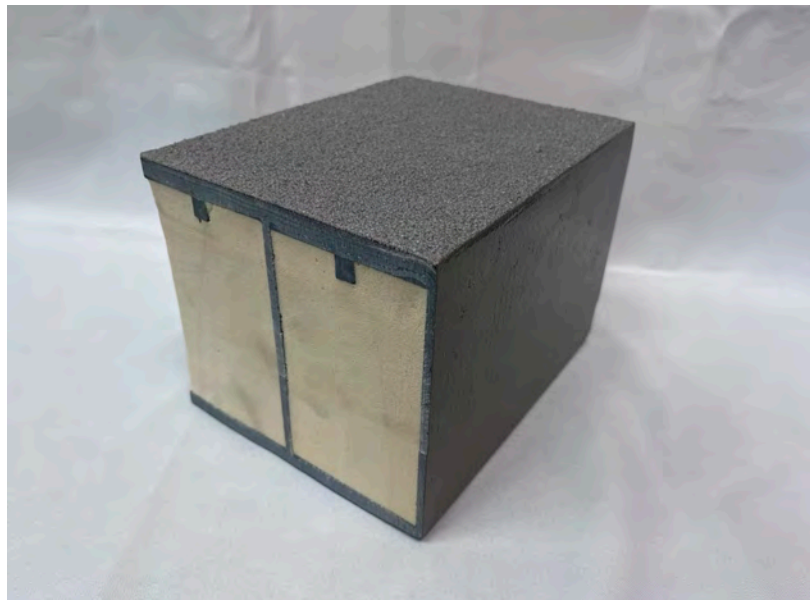
FRP pedestrian bridges constructed with materials other than E-glass fibers and vinyl ester or isophthalic polyester resins, or manufactured using processes other than pultrusion and VIP molding, shall meet the provisions of Section 6.3.

with a closed-cell foam core. A cross section of a VIP-molded FRP sandwich panel is shown in Figure C1.7-2.

These Guide Specifications include requirements for the testing and validation of FRP pedestrian bridges constructed using other manufacturing processes.



**Figure C1.7-1—Pultruded FRP Planks Placed Side-by-Side** (Source: Creative Composites Group)



**Figure C1.7-2—Section of a VIP-Molded FRP Panel**  
(Source: Creative Composites Group)