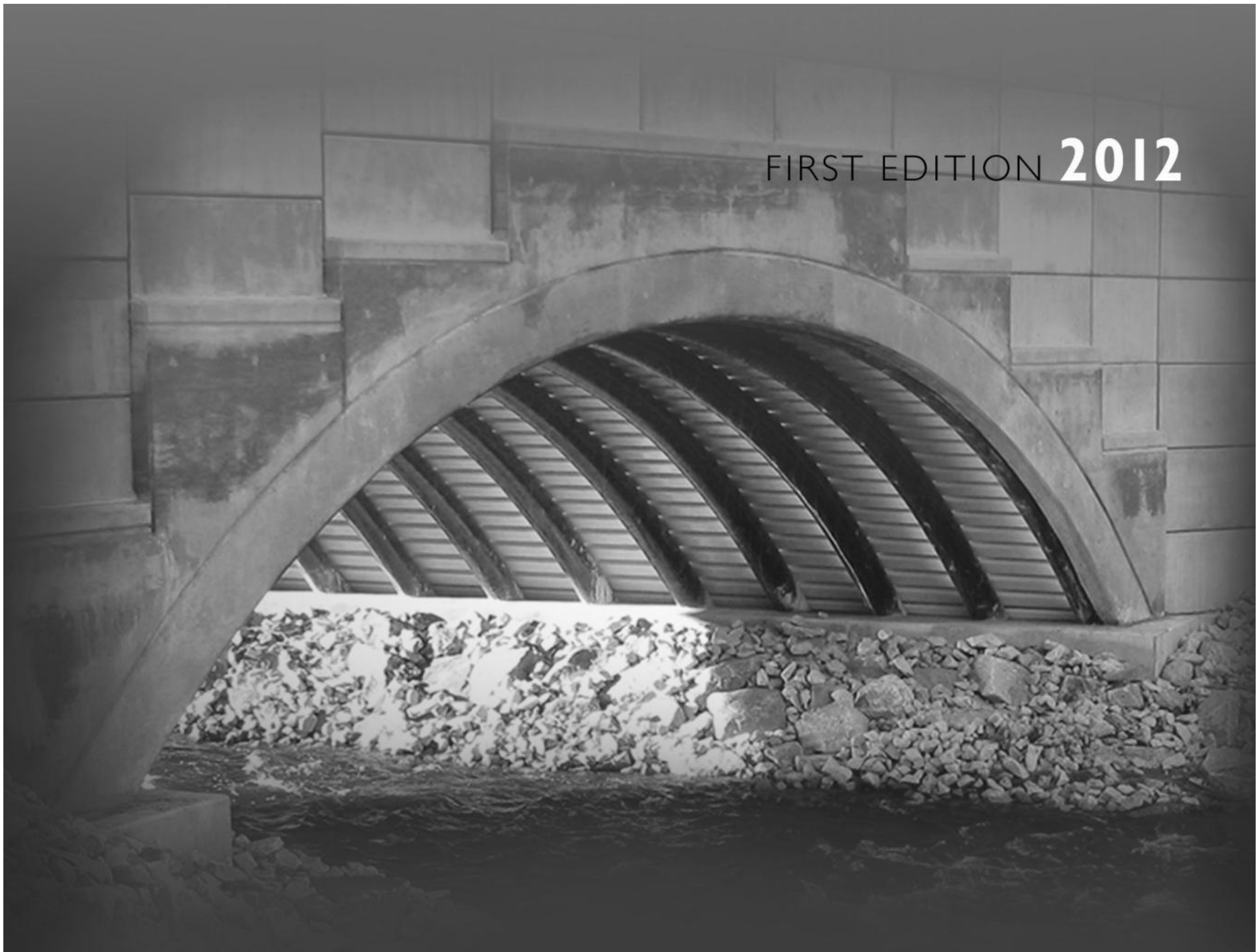
FIRST EDITION 2012



LRFD GUIDE SPECIFICATIONS

FOR DESIGN OF CONCRETE-FILLED

FRP TUBES FOR FLEXURAL AND AXIAL MEMBERS

American Association of State Highway and Transportation Officials

AASHTO
The Voice of Transportation

FOREWORD

LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes for Flexural and Axial Members, First Edition (2012) was developed as a collaborative effort between Dr. Amir Fam of Queen's University, Ontario, the University of Maine, and Advanced Infrastructure Technologies with review and approval by the AASHTO T-6 Technical Subcommittee for Fiber-Reinforced Polymer Composites.

The basis of this document was derived from a large body of research published over the past 15 years by a variety of research institutions. These resources can be found in the references sections of this document.

AASHTO Subcommittee on Bridges and Structures

PREFACE

This new AASHTO publication, *LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes for Flexural and Axial Members*, First Edition (2012), comprises three sections:

Section 1—Introduction

Section 2—Concrete-Filled FRP Tubes (CFFTs)

Section 3—Material Specifications

A list of references is included at the end of each section.

AASHTO Publications Staff
December 2012

TABLE OF CONTENTS

TABLE OF CONTENTS

SECTION 3: MATERIAL SPECIFICATIONS

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

1.1—SCOPE

These Specifications present provisions for the analysis and design of concrete-filled fiber-reinforced polymer (FRP) tubes (CFFT) for use as structural components in bridges. Design methodology presented in this specification allows CFFTs to be designed as flexural members, axial compression members, or members subjected to combined flexural and axial compression, in addition to shear. CFFT bridge components may include beams, arches, columns, and piles.

C1.1

FRP materials have emerged as an alternative material to steel reinforcement for concrete structures. They offer advantages over steel reinforcement due to their noncorrosive nature and nonconductive behavior. FRP is a also a versatile material that can be produced in many forms such as reinforcing bars, grids, rigid plates, flexible sheets, and several structural shapes, including tubes. This specification is focused on one application of FRP in the form of tubes used as structural stay-in-place forms filled with concrete [Fardis and Khalili (1981), Nanni and Bradford (1995), Mirmiran and Shahawy (1996), Davol (1998), Burgueño (1999), Fam (2000), Fam and Rizkalla (2001), Fam and Rizkalla (2002)]. Due to differences in the physical and mechanical behavior of FRP materials as opposed to steel, particularly when used as stay-in-place structural forms, unique guidance on the engineering and construction of bridge components using this technology is needed.

These Specifications are not intended to supplant proper training or the exercise of judgment by the Design Professional, and state only the minimum requirements necessary to provide public safety. The Owner or the Design Professional may require the sophistication of the design or the quality of materials and construction, or both, to be higher than the minimum requirements.

The Design Professional shall be familiar with the provisions of the *AASHTO LRFD Bridge Design Specifications*, 6th Edition (AASHTO, 2012), hereafter referred to as "AASHTO LRFD," and the latest interim revisions, as well as with the design of conventional reinforced concrete structures and structures exposed to earth loading.

The commentary directs attention to other documents that provide suggestions for carrying out the requirements and intent of these Specifications. However, those documents and this commentary are not intended to be a part of these Specifications.

1.2—DEFINITIONS

Composite Action—A condition in which two or more elements or components are made to act together by eliminating relative movements at their interface.

Design Professional—The architect, engineer, architectural firm, or engineering firm responsible for the design of the bridge and issuing Contract Documents or administering the Work under Contract Documents, or both.

Fiber—Any fine thread-like natural or synthetic object of mineral or organic origin. Note: This term is generally used for materials whose length is at least 100 times its diameter.

Fiber, Aramid—Highly oriented organic fiber derived from polyamide incorporating an aromatic ring structure.

Fiber, Carbon—Fiber produced by heating organic precursor materials containing a substantial amount of carbon, such as rayon, polyacrylonitrile (PAN), or pitch in an inert environment.

Fiber, Glass—Fiber drawn from an inorganic product of fusion that has cooled without crystallizing.

1.3—LIMITATIONS

Composite action between the concrete core and FRP tube is required for a CFFT member to develop its stiffness and strength as defined in these Specifications. CFFTs that do not have sufficient bond between the concrete core and FRP tube to ensure composite action are not addressed in these Specifications. Composite action shall be verified in accordance with Article 2.5. The assumed failure mechanism of CFFTs used as flexural members shall not be based on the formation of plastic hinges. CFFTs shall not be used as ductile earthquake resisting elements.

C1.3

Bond may be achieved by shear interlock mechanism, such as a roughened inner surface of the FRP tube or friction, or both, that can be further enhanced by the use of low-shrinkage or expansive concrete. FRP materials demonstrate a linear-elastic behavior up to failure and do not demonstrate yielding, which is the basis for plastic hinge formation and moment redistribution.

1.4—DESIGN PHILOSOPHY

These Specifications are based on limit state design principles where structural components shall be proportioned to satisfy the requirements at all appropriate service, fatigue and creep rupture, strength, and extreme event limit states. In many instances, serviceability or fatigue and creep rupture limits may control the design.

Provisions related to limit states analyses, general design and location features, loads and load factors, and structural analysis and evaluation shall be in compliance with AASHTO LRFD.

C1.4

The limit states specified herein are intended to provide for a buildable, serviceable bridge, capable of safely carrying design loads for a specified lifetime.

1.5—REFERENCES

AASHTO. 2012. *AASHTO LRFD Bridge Design Specifications, 6th Edition with Interims*, American Association of State Highway and Transportation Officials, Washington DC.

Burgueño, R. 1999. "System Characterization and Design of Modular Fiber Reinforced Polymer (FRP) Short- and Medium-Span Bridges," Doctoral dissertation, UMI No. 9928617, University of California, San Diego, CA.

Davol, A. 1998. "Structural Characterization of Concrete Filled Fiber Reinforced Shells," Doctoral dissertation, University of California, San Diego, CA.

Fam, A. 2000. "Concrete-Filled Fibre-Reinforced Polymer Tubes for Axial and Flexural Structural Members." Doctoral dissertation, Univeristy of Manitoba. Winnepeg, Manitoba, Canada.

Fam, A. and S. Rizkalla. 2001. "Confinement Model for Axially Loaded Concrete Confined by Circular Fiber-Reinforced Polymer Tubes," *ACI Structural Journal* 98(4), pp. 451–461. American Concrete Institute, Farmington Hills, MI.

Fam, A. and S. Rizkalla. 2002. "Flexural Behavior of Concrete-Filled Fiber-Reinforced Polymer Circular Tubes," *Journal of Composites for Construction*, 6(2), pp. 123–132. American Society of Civil Engineers, Reston, VA.

Fardis, M. N. and H. Khalili. November–December 1981. "Concrete Encased in Fibreglass-Reinforced Plastic," *ACI Structural Journal*, Title No. 78-38, pp. 440–446. American Concrete Institute, Farmington Hills, MI.

Mirmiran, A. and M. Shahawy. 1996. "A New Concrete-Filled Hollow FRP Composite Column," *Composites Part B: Engineering*, Special Issue on Infrastructure, Elsevier Science Ltd., 27B (3–4), pp. 263–268. Elsevier, Amsterdam, The Netherlands.

Nanni, A. and N. Bradford. 1995. "FRP Jacketed Concrete under Uniaxial Compression," *Construction and Building Materials*, 9(2), pp. 115–124. Elsevier, Amsterdam, The Netherlands.