IN-LB	Inch-Pound Units
SI	International System of Units

Design of Circular Concrete-Filled Fiber-Reinforced Polymer Tubes—Guide

Reported by ACI Committee 440

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The circular concrete-filled fiber-reinforced polymer (FRP) tube (CFFT) system is an alternative to traditional reinforced concrete structures. The pre-cured FRP tube, which comprises layers of engineered fibers oriented in different directions, provides a corrosion-resistant stay-in-place structural form to retain freshly cast concrete that speeds up construction while at the same time provides primary reinforcement in the two orthogonal directions instead of traditional longitudinal steel reinforcing bar, ties, and stirrups. Typical applications of CFFT include piles, columns, and poles used in building and bridge construction. The FRP tube provides confinement and environmental protection of the concrete core, increasing its strength, ductility, and durability, as well as protection of the minimum internal steel reinforcement. Due to the unique characteristics of CFFTs in which reinforcement in the orthogonal directions are integrated into one continuous membrane—namely, the tube—specific guidance on the design of members using this system is needed. This guide provides general information and background of CFFT technology, including applications and limitations, characteristics of circular FRP tubes, and the interface bond between tube and concrete. The guide provides provisions for design for flexure, axial load, shear, combined loading, connections, and a design approach aimed at mitigating the risk of accidental tube loss. This guide is based on the knowledge gained from experimental research, analytical work, and field applications of CFFTs.

Keywords: bond; circular; concrete-filled fiber-reinforced polymer tube (CFFT); confinement; connections; fiber-reinforced polymer (FRP); stay-in-place form; tube.

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CONTENTS

CHAPTER 1—INTRODUCTION

Fiber-reinforced polymer (FRP) materials have emerged as an alternative to steel reinforcement for concrete structures. Unlike steel reinforcement, FRP reinforcement does not corrode. FRP is a versatile material that can be produced in many forms such as reinforcing bars, grids, rigid plates, flexible sheets, and structural shapes that include tubes. This guide is focused on the application of FRP in the form of precured tubes used as structural stay-in-place formwork filled with concrete (Fardis and Khalili 1981; Nanni and Bradford 1995; Mirmiran and Shahawy 1996). Due to differences in the physical and mechanical properties of FRP materials as opposed to steel, particularly when used as concrete-filled tubes, specific guidance on the engineering design of structural components using this technology is needed.

Concrete-filled FRP tubes (CFFTs) are viable high-performance systems for applications subject to harsh environments. The FRP tube acts as corrosion-resistant reinforcement, increasing section capacity of the system under axial, flexural, and shear loading; provides confinement and protection of the concrete core; and functions as stay-in-place formwork to achieve rapid construction. The fiber orientations in the FRP tube are designed to provide strength and stiffness in the desired directions, which may be tailored depending on the structural application. Fibers aligned along the longitudinal axis (or near-longitudinal in compliance with 1.4.1) of the tube provide strength and stiffness under bending and combined bending and axial loads. Fibers perpendicular to the longitudinal axis (or near-perpendicular in compliance with 1.4.1) provide confinement to the concrete. This design is referred to as cross-ply or near-cross-ply laminate. Other tube designs include angle-ply laminate with fibers at large angles from the longitudinal axis, or a combination of angle-ply and cross-ply laminates in the same tube.

1.1—Scope

This guide provides recommendations for the design of circular CFFTs for use as structural components. Other shapes such as rectangular sections are beyond the scope of this document. The contribution of internal reinforcement exceeding the minimum needed to compensate for accidental damage of the FRP tube, discussed in Chapter 9, or used to prestress the CFFT is not considered in this document. Design methodologies presented in this guide allow CFFTs to be designed as flexural members, axial compression members, or members subjected to combined flexure and axial compression. CFFT components include beams, arches, columns, load-bearing piles, and mono-poles.

The design recommendations in this guide were developed based on research conducted on FRP tubes composed