Guide to Fiber-Reinforced Shotcrete

Reported by ACI Committee 506

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*Subcommittee members who prepared this report.
†Subcommittee Chair.

This guide describes the technology and applications of fiber-reinforced shotcrete (FRS) using synthetic and steel fibers. Mechanical properties, particularly toughness, impact, and flexural strength, are improved by fiber addition, and these improvements are described along with other typical properties and benefits, such as control of shrinkage cracking. Proportions of typical mixtures, batching, mixing, and application procedures are described, including methods of reducing rebound and equipment used to apply FRS. Applications of FRS are described, including rock-slope stabilization work, construction and repair of tunnel and mining linings, fire explosive spalling-resistant linings, channel linings, pools and rockscapes, and structure repair. Available design information is briefly discussed, and design references are listed.

Keywords: fiber-reinforced shotcrete; fibers; linings; mining; repair; steel fibers; synthetic fibers; tunnels.

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ACI 506.1R-08 supersedes ACI 506.1R-98 and was adopted and published November 2008.

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Fiber-reinforced shotcrete (FRS) is mortar or concrete containing discontinuous discrete fibers that is pneumatically projected at high velocity onto a surface. Continuous meshes, woven fabrics, and long rods are not considered as discrete fiber-type reinforcing elements in this guide.

1.2—Scope

This document provides information on fiber-reinforced shotcrete using synthetic and steel fibers. Topics covered include materials used, mixture proportions, production of shotcrete, testing procedures, performance of FRS, design considerations (including an example in the Appendix), specifications, and some examples of applications.

1.3—Historical background

FRS with steel fibers was first placed in North America early in 1971 in experimental work directed by Lankard, et al. (1971). Steel FRS (SFRS) was proposed for underground support by Parker in 1971 (Parker 1974). Additional trials were made by Poad in an investigation of new and improved methods of using shotcrete for underground support (Poad et al. 1975). Subsequently, the first practical applications of SFRS were made in a tunnel adit at Ririe Dam, ID in 1973 (Kaden 1977). Since that time, SFRS has been used throughout the world. Shotcrete using micropolypropylene fibers was first placed in Europe in 1968 (Hannant 1978). Macrosynthetic fibers for use in shotcrete were developed in the mid-1990s and have been used in mining and slope stabilization projects (Morgan and Heere 2000).

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_S = area of conventional steel per unit width
a = $A_S f_Y / 0.85 f'_c b$
b = unit width of section
d = moment arm from loaded surface to center of reinforcement
f_{600}^{100} = post-cracking residual flexural strength of a 4 in. (100 mm) deep beam as determined at 0.02 in. (0.5 mm) deflection (Span/600) using ASTM C1609/C1609M
f_Y = yield strength of conventional reinforcement
f'_c = compressive strength of shotcrete
t = FRS section thickness
ϕ = strength reduction factor, = 0.9 for flexure

2.2—Definitions

aspect ratio, fiber—the ratio of length to diameter of a fiber in which the diameter may be an equivalent diameter.

denier—measure of fiber diameter, taken as the mass in grams of 9000 m (29,528 ft) of the fiber.

equivalent diameter, fiber—diameter of a circle with an area equal to the cross-sectional area of the fiber.

macrofiber—a fiber with an equivalent diameter greater than or equal to 0.012 in. (0.3 mm) for use in concrete.

microfiber—a fiber with an equivalent diameter less than 0.012 in. (0.3 mm) for use in concrete.

CHAPTER 3—MATERIALS

3.1—General

FRS is conventional shotcrete with fibers added. Materials for use in FRS should conform to the requirements of ASTM C1436, which covers the typical materials used in shotcrete, including chemical and mineral admixtures, fibers, and the combined grading of aggregates for fine and coarse mixtures: Grading No. 1: No. 4 to No. 100 sieve (4.75 mm to 150 μm), and No. 2: 3/8 in. to No. 100 sieve (9.5 mm to 150 μm).