Guide for Specifying, Proportioning, and Production of Fiber-Reinforced Concrete

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This guide covers specifying, proportioning, mixing, placing, and finishing of fiber-reinforced concrete (FRC). Much of the current conventional concrete practice applies to FRC. The emphasis in the guide is to describe the differences between conventional concrete and FRC and how to deal with them. Sample mixture proportions are tabulated. Guidance is provided in the mixing techniques to achieve uniform mixtures, placement techniques to assure adequate consolidation, and finishing techniques to assure satisfactory surface textures. A listing of references is provided covering proportioning, properties, applications, shotcrete technology, and general information on FRC.

Keywords: fiber; fiber-reinforced concrete; production; proportioning; specification.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Fiber-reinforced concrete (FRC) is a composite material made of hydraulic cements, water, fine and coarse aggregate, and a dispersion of discontinuous fibers. In general, fiber length varies from 0.25 to 2.5 in. (6 to 64 mm). FRC may also contain supplementary cementitious materials and admixtures commonly used with conventional concrete.

The most common steel fiber diameters are in the range of 0.02 to 0.04 in. (0.5 to 1.0 mm) and a specific gravity of 7.85. Steel fiber shapes include round, oval, polygonal, and crescent cross sections, depending on the manufacturing process and raw material used.

Two general sizes of synthetic fibers have emerged: microsynthetic and macrosynthetic fibers. Microsynthetic fibers are defined as fibers with diameters or equivalent diameters less than 0.012 in. (0.3 mm), and macrosynthetic fibers have diameters or equivalent diameters greater than 0.012 in. (0.3 mm). Polypropylene fibers can be either microsynthetic or macrosynthetic, and have a specific gravity of 0.91. Nylon fibers, generally microfibers, have a specific gravity of 1.14.

Microsynthetic fibers are typically used in the range of 0.05 to 0.2% by volume, while steel fibers and macrosynthetic fibers are used in the range of 0.2 to 1% by volume, and sometimes higher in certain applications. For example, 2% by volume and higher of steel fibers is common for security applications such as vaults and safes. These dosages equate to 0.75 to 3 lb/yd^3 (0.44 to 1.8 kg/m^3) for microsynthetic fibers, 3 to 15 lb/yd^3 (1.8 to 9 kg/m^3) for macrosynthetic fibers, and 26 to 132 lb/yd^3 (15 to 78 kg/m^3) for steel fibers.

Glass fibers for use in concrete should be alkali-resistant (AR) glass to prevent loss of strength due to the high alkalinity of the cement-based matrix. Glass fibers need to contain a minimum of 16% by mass of zirconium dioxide (zirconia) to be considered as alkali resistant. AR glass fiber monofilaments are either 0.0005 or 0.0007 in. (13 or 18 μm) in diameter, with specific gravity of 2.7.

AR glass fiber chopped strands can be provided in two basic types: dispersible fibers and internal strands. Dispersible fibers quickly disperse into individual monofilaments when mixed into the concrete. These fibers are considered to be microfibers. The addition rate for this type of AR glass fiber is typically 0.5 to 1.5 lb/yd^3 (0.29 to 0.88 kg/m^3). This corresponds to a range from 0.01 to 0.03% by volume. This type of glass fiber is used mostly for plastic shrinkage crack control. Integral strands are bundles of monofilaments that stay integral as bundles through mixing and into the cured concrete. Integral strands are available in bundles of 50, 100, and 200 monofilaments. These strands are considered as macrofibers, and can be added at higher fiber contents, typically 4 to 8 lb/yd^3 (2.35 to 4.7 kg/m^3) corresponding to 0.09 to 0.17% by volume. Addition rates of up to 25 lb/yd^3 (14.7 kg/m^3) or 0.55% by volume have also been used with higher cement contents.

Natural fibers and synthetic fibers, such as carbon, acrylic, and aramid fibers, have been used in specialized FRC and are not discussed in this guide. The use of glass fibers in the spray-up process is also not discussed in this guide. Information on these fiber types may be found in ACI 544.1R.

The addition of fibers affects the plastic and hardened properties of mortar and concrete. Depending on the fiber material, length and diameter, deformation geometry, and the addition rate, many properties are improved, notably plastic shrinkage cracking, impact resistance, and toughness or ductility. Flexural strength, fatigue and shear strength, and the ability to resist cracking and spalling can also be enhanced by providing the composite material with some postcracking (residual) strength in either the plastic or hardened state. More detailed information on properties may be found in ACI 544.1R and 544.2R.

1.2—Scope

This guide covers specifying, proportioning, mixing, placing, and finishing of conventional FRC. The fiber types