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Report on the Measurement of Fresh State Properties and Fiber Dispersion of Fiber-Reinforced Concrete

Reported by ACI Committee 544

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American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

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*Members of subcommittee who contributed to the document.
†Chair of the Subcommittee C who developed the document.

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This report outlines existing procedures for testing and measuring fresh state performance and fiber dispersion in fiber-reinforced concrete (FRC). As for the former, test methods applicable to both ordinary vibrated FRC and fiber-reinforced self-consolidating concrete (FR-SCC) are reviewed. Methods for nondestructive monitoring of fiber dispersion and orientation in FRC materials and structures are also presented and their pros and cons addressed.

Keywords: fiber dispersion; fiber-reinforced concrete; fresh state performance; nondestructuive testing; self-consolidating fiber-reinforced concrete.

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CONTENTS

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

The use of fiber-reinforced concrete (FRC) has evolved from experimental small-scale applications to routine factory and field applications involving the use of tens of millions of cubic yards (meters) each year globally. This has created a need to review existing test methods and, where necessary, develop new methods for determining the fresh and hardened properties of FRC that may be of interest for different engineering applications and may be required at different stages of the design, construction, and maintenance process. These methods are presented in an effort to standardize test procedures and equipment, and also to ensure that test results from different sources can be compared effectively. Whereas it is recognized that the use of procedures and equipment other than those discussed in this report may be employed because of past practices or availability of equipment, the use of standard tests facilitates the comparison of information, promotes the development or broadening of the data base needed to consistently quantify properties of the various types of FRC, and is preferable to nonstandard variants. Such data are also instrumental in developing consistent and internationally recognized design procedures that are based on standard measurements of relevant properties of the material, as well as in formulating reliable performance criteria to classify and accept the material.

Although most of the test methods described in this report were developed initially for steel FRC (SFRC), they are also applicable to concretes reinforced with glass, polymeric, and natural fibers, except when noted.

As the applications of FRC are being expanded and new fibers are introduced to the market, some existing test methods may be found insufficient or unable to provide meaningful data. Therefore, changes can be applied and, in these instances, care taken in consideration of the issues of repeatability and reproducibility of test results. Repeatability is defined as the variability among replicate test results obtained on the same material within a single laboratory or job site by one operator. Reproducibility refers to variability among test results obtained on the same material in different laboratories, job sites, or both. Regarding reproducibility, users are advised to carefully check the applicability of the test methods, both in lab conditions and in the field, as differences may exist between them.

1.2—Scope

This report applies to the measurement of fresh state and fiber-dispersion properties of both conventionally mixed and placed (vibrated) FRC and fiber-reinforced self-consolidating concrete (FR-SCC) using steel, glass, polymeric carbon, minerals (such as basalt), and natural fibers.

The test methods reported herein are also applicable to ultra-high-performance concrete (UHPC). It is worth remarking that, generally, UHPC does not contain coarse aggregates and is employed in combination with reduced or no amounts of conventional reinforcement. In view of this, care should be taken in assessing the significance of the results, as far as the consistency is concerned, of the volume of material employed in the tests with reference to the heterogeneity scale of the mixture (maximum aggregate size, maximum fiber length). Moreover, passing ability tests, such as the ones reviewed in 3.2.2, may also provide information of limited significance.

This report does not relate to thin glass FRC or mortar products produced by the spray-up process. The Prestressed Concrete Institute (1981), International Glassfibre Reinforced Concrete Association (2016a,b), and ASTM C1116/C1116M contain recommendations for test methods for these spray-up materials.

Measurement of the properties of fiber-reinforced shotcrete (FRS) that contain the aforementioned fiber types can be performed using the test methods described herein. Special procedures may be required to cast specimens or obtain them from existing structures, as well as to measure properties specific to shotcreting technology. Relevant provisions can be found in ACI 506.2.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

c = clear gap spacing in L-box test
d_f = fiber diameter, in. (mm)
d_{max} = maximum diameter of the flow spread in J-ring test, in. (mm)
d_{perp} = diameter measured perpendicular to the maximum diameter d_{max} in J-ring test, in. (mm)
l_f = fiber length, in. (mm)
R = electrical resistivity of fiber-reinforced concrete or fiber-reinforced cementitious composite, ohm
R_m = electrical resistivity of the parent plain concrete (matrix), ohm
T_{20} or T_{500} = time for the flow spread to reach a diameter of 20 in. (500 mm) in slump flow test, s (in European literature, it has been referenced as T_{50}, where 50 represents the threshold diameter in cm)
T_{final} = time for the flow spread to reach the final slump-flow diameter in slump flow test, s
T_V = V-funnel flow time, that is, time for the fluid concrete filling the funnel to completely come out once the nozzle of the funnel is opened, s
V_f = fiber volume fraction (generally expressed in percent)
γ = filling capacity in filling box test