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Test methods for discrete polymer fibre for fibre-reinforced cementitious composites

Méthodes d'essai des fibres polymères distinctes pour les composites à base de ciment renforcés par des fibres

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 6, *Non-traditional reinforcing materials for concrete structures*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Polymer fibre in this document means a fibre made with macromolecule substances as raw material such as aramid fibre, polyamide fibre, polyester fibre, polyethylene fibre, polypropylene fibre, polyvinylalcohol fibre. For fibre-reinforced cementitious composites (FRCC), many kinds of and types of polymer fibres are designed and produced on various demands. However, standards of discrete polymer fibres for FRCC in the civil engineering field are not specified yet despite the need for it.

If the fibre suppliers can show the principal fibre properties such as geometry and standardized basic mechanical properties, the engineer can design, manufacture and practice more effectively. Therefore, although the standard of the fibre itself is useful for users, construction engineers and others, it is expected to be used primarily by more fibre suppliers than those.

The status of the existing standards is as follows;

1) Test methods for composites exist, i.e. ISO 19044, ISO 21022 and ISO 21914. However, they are not for polymer fibre itself. Breaking force and elongation at break for the fibre itself are specified in ISO 2062, but other material properties of fibres, such as initial modulus of elasticity and thermal properties, are not specified.

2) Existing standards for fibres are intended for clothing textiles, ropes or strips. Test methods and unit system are different from those in the civil engineering field. The traditional unit system for textile is the Tex system, in which sectional size of fibre is expressed by weight per length. The unit system is different from that used in the civil engineering field. It would be very convenient to express them in SI units such as Newtons – millimetres.

The purpose of each testing item is described below.

For a fibre design, the fibre shape and mechanical properties are important for selection. The fibre length is selected upon the matrix composition. For example, a 4 mm to 12 mm length fibre is suitable for a uniform matrix such as cement mortar, and 20 mm or longer is required for concrete that includes coarse aggregates. The fibre diameter is also important because it influences the fibre dispersion through the fibre aspect ratio (length/diameter). The tensile strength and initial modulus of elasticity are key parameters that influence the reinforcing performance of the fibre through the fibre-to-matrix bond. On the other hand, the bonding strength, friction and surface treatment of fibre, in spite of their importance, are not included in this document as they are strongly related to the matrix properties and are generally difficult to estimate. In addition, creep and fatigue properties are not included in this document either because the needs of these properties depend on the application situations of the FRCC.

In terms of fibre usage, the fibre reinforcement performance in the FRCC is related to the fibre volume fraction, which is calculated from the fibre weight according to the fibre density. In the use of moisturized fibre products for a uniform fibre dispersion, the existence of water can have a significant effect on the hydration of the cementitious matrix. Thus, the fibre moisture content needs to be accurately estimated.

For the operation stage of the FRCC, their thermal properties and durability against chemicals are of particular concern. For instance, in case of high strength cementitious composites, the polymer fibre can melt during a fire to introduce small cavity so as to release the high internal pressure and consequently reduce the risk of an explosive failure of the cement matrix. Therefore, for fire protection applications, a relatively low melting point of the fibre is considered as apriority. In addition, fibres for the FRCC need to have high durability against alkaline conditions. Thus, the melting point and alkaline durability are two important parameters of the fibres.

The fibre properties are defined in this document as the properties of the smallest fibre unit that disperses in the FRCC. In actual application, fibres can also exist in the form of bundle even within the FRCC.

Test methods for discrete polymer fibre for fibre-reinforced cementitious composites

1 Scope

This document specifies the test methods for discrete polymer fibre for fibre-reinforced cementitious composites (FRCC).

This document defines the test methods for discrete polymer fibre, such as diameter, length, tensile strength, initial modulus of elasticity, density, melting point, moisture content and alkaline durability as basic items. These are test methods intended for certification of a fibre and not for quality control or field acceptance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pycnometer method and titration method*

ISO 1183-2, *Plastics — Methods for determining the density of non-cellular plastics — Part 2: Density gradient column method*

ISO 1183-3, *Plastics — Methods for determining the density of non-cellular plastics — Part 3: Gas pyknometer method*

ISO 11357-3, *Plastics — Differential scanning calorimetry (DSC) — Part 3: Determination of temperature and enthalpy of melting and crystallization*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
fibre-reinforced cementitious composite
FRCC
concrete or mortar containing short discrete fibres that are distributed in the matrix

3.2
standard atmosphere
condition of an atmosphere with temperature of (20 ± 2) °C and relative humidity of (65 ± 4) %

3.3
standard condition
condition in *standard atmosphere* (3.2) for a period of at least 24 h

3.4
tenacity
tensile strength of fibre in cN/dtex

3.5
filament yarn
long and continuous fibre which has not been cut for fibre diameter determination or cut to the product length

3.6
consecutive fibre
long and continuous fibre for fibre diameter determination which is longer than the *chopped fibre* (3.7) products

3.7
chopped fibre
short fibre which is cut to the product length

3.8
individual fibre
smallest unit of fibre structure in fibre-reinforced cementitious composite

Note 1 to entry: "tex" expresses the unit that shows the sectional size of the individual fibre in weight (grams) per 1 000 m of fibre.

4 Symbols and abbreviated terms

c	cN/dtex	tenacity	7.4
d	mm	nominal value of individual fibre diameter	5.1
d_f	mm	measured value of individual fibre diameter	5.1, 5.2, 7.4, 7.5
E_{ini}	N/mm^2	initial modulus of elasticity	7.5
$\overline{f_{f0}}$	N/mm^2	average value of tensile strength of non-exposure specimen	11.7
$\overline{f_{f1}}$	N/mm^2	average value of tensile strength of alkaline exposed specimen	11.7
f_f	N/mm^2	tensile strength	7.4
l	m	length of specimen	5.1
L_f	mm	measured value of fibre length	5.2
L_F	mm	winding frame length in Figure 2	11.2
l_g	mm	grip length in tensile test	11.2
l_{test}	mm	gauge length in tensile test	7.5, 11.2
m	g	mass of specimen	5.1, 5.2, 10.1
m'	g	sample mass in standard condition	10.1
M_w	%	moisture content	10.1
n_f		number of fibres in yarn	5.1, 7.4, 7.5
P_A	N	load at point A	7.5
P_{max}	N	maximum tensile load	7.4
R_{et}	%	tensile strength retention	11.7
T_m	°C	melting point	9.1
δ_{ini}	mm	elongation at initial slope in tensile load – elongation curve	7.5
ρ	g/cm^3	density	5.1, 5.2, 7.4

5 Test methods for determining fibre diameter

5.1 Consecutive fibre method

a) Cut out filament yarns to make specimen referring to Table 2. Specimens are prepared by cutting out from each package without first layer. Take five specimens per package, each with a length according to Table 2 with an accuracy of 0,1 %. Use an appropriate metering device under a tension of 0,05 cN/dtex, with a tolerance of ±10 %. For fibres with diameters less than 0,5 mm, use a wrap reel. For diameters 0,5 mm and above, use a scale.

Table 2 — Specimen length

Nominal diameter, *d* mm	**Length, *l*** m
$d < 0{,}08$	250
$0{,}08 \leq d < 0{,}30$	100
$0{,}3 \leq d < 0{,}5$	10
$0{,}5 \leq d$	5

b) Condition the specimens before testing in the standard condition.

c) Measure the mass of the conditioned specimens, *m*, with an accuracy of 0,1 % in a standard atmosphere.

d) Calculate the fibre diameter with Formula (1):

$$d_f = 2\sqrt{\frac{m}{\pi \times l \times \rho \times n_f}} \tag{1}$$

Formula (1) is derived from Formula (2), which determines *m*:

$$m = \pi\left(\frac{d_f}{2}\right)^2 \times 1\,000 \times l \times \frac{\rho}{1\,000} \times n_f \tag{2}$$

Calculate the average value of the five or more results. The results shall be rounded off with a precision of three significant digits. If required, calculate the standard deviation and a 95 % confidence interval.

5.2 Chopped fibre method

a) Pick up 200 chopped fibre specimens for five or more times from the same package.

b) Condition the specimens before testing in the standard condition.

c) Measure the mass of the conditioned specimens, *m*, with an accuracy of 0,1 % in the standard atmosphere.

d) Calculate the fibre diameter with Formula (3):

$$d_f = 2\sqrt{\frac{5 \times m}{\pi \times L_f \times \rho}} \tag{3}$$

Formula (3) is derived from Formula (4), which determines *m*:

$$m = \pi\left(\frac{d_f}{2}\right)^2 \times L_f \times \frac{\rho}{1\,000} \times 200 \tag{4}$$

Calculate the average value of the five or more results. The results shall be rounded off with a precision of three significant digits. If required, calculate the standard deviation and a 95 % confidence interval.

NOTE The vibroscope method in ISO 1973 can be used under the agreement of the parties concerned.

5.3 Test report

The test report shall include the following items:

a) fibre profile (type of fibre, nominal value of fibre diameter, nominal value of fibre length, and supplier);

b) conditioning status;

c) number of specimens (consecutive fibre method) or number of specimens set (chopped fibre method);

d) length of specimen (consecutive fibre method) or measured value of fibre length (chopped fibre method);

e) mass of specimen;

f) density used in calculation;

g) measured value of fibre diameter;

h) any deviations from the procedure;

i) any unusual features observed;

j) the date of the test;

k) a reference to this document (i.e. ISO 23523:2021).

6 Test method for determining fibre length

6.1 Procedure

a) Pick up 200 or more chopped fibre specimens from the same package.

b) Condition the specimens before testing in the standard condition.

c) Measure the length of the specimen by a scale in millimetres.

d) Calculate the average value of the length, L_f. The results shall be rounded off with a precision of 1 mm;

6.2 Test report

The test report shall include the following items:

a) fibre profile (type of fibre, nominal value of fibre diameter, nominal value of fibre length, supplier);

b) conditioning status;

c) number of specimens;

d) measured value of fibre length;

e) any deviations from the procedure;

f) any unusual features observed;

