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Test methods for fibre-reinforced cementitious composites — Bending moment — Curvature curve by four-point bending test

Méthodes d'essai des composites à base de ciment renforcés par des fibres — Moment de flexion — Courbe de courbure par essai de flexion quatre points

Reference number
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Foreword

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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*.

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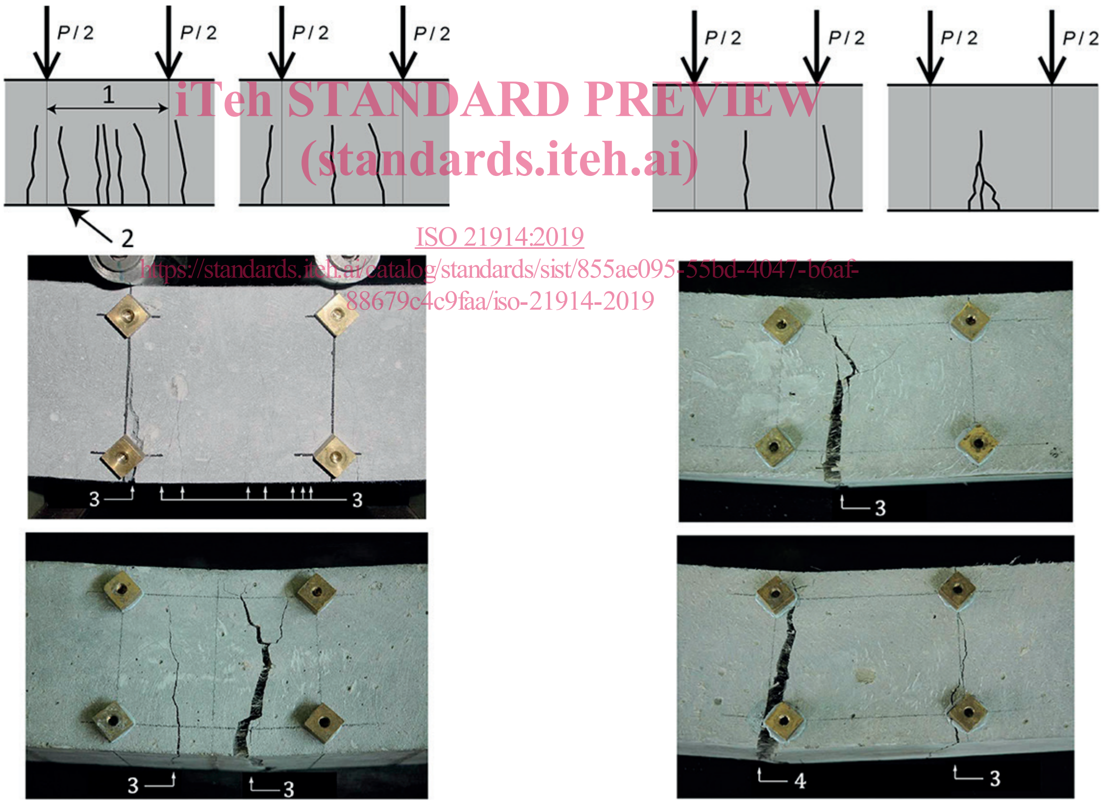
Test methods for fibre-reinforced cementitious composites — Bending moment — Curvature curve by four-point bending test

1 Scope

This document specifies the test method for obtaining bending moment-curvature curves of fibre-reinforced cementitious composites (FRCCs) through four-point bending test of prism specimens.

It is applicable to FRCCs that show separated multiple cracks under pure bending before maximum load.

NOTE Separated multiple cracks means two or more independent cracks visible to the eye occurring in the constant moment span from the bottom side over half depth of the specimen before maximum load is observed, as shown in Figure 1. For the purpose of confirmation of cracks, spraying up the specimen surface using an alcohol solution or acetone makes observations easier. The formation of multiple cracks is associated with deflection hardening behaviour. For FRCCs that do not show separated multiple cracks, see ISO 19044.



a) Applicable b) Not applicable

Key

1 constant moment span

2 crack visible to the eye

3 crack

4 crack (out of constant moment span)

P applied load

Figure 1 — Cracking in FRCCs covered by this document

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 1920-3:—[1], *Testing of concrete — Part 3: Making and curing test specimens*

ISO 1920-4:—[2], *Testing of concrete — Part 4: Strength of hardened concrete*

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 distributed throughout matrix

Note 1 to entry: Fibres include man-made fibres (e.g., metallic fibres, inorganic fibres, synthetic fibres) and natural fibres.

3.2
average strain
ratio of axial deformation to gauge length

3.3
average curvature
gradient of *average strains* (3.2) in constant moment span

4 Symbols

See Table 1.

Table 1 — Symbols

Symbol	Unit	Description	Subclause
b	mm	width of cross-section of specimen	5.1
D	mm	depth of cross-section of specimen	5.1
d_0	mm	distance between two LVDTs	6.4
L	mm	overall length of specimen	5.1
M	N·mm	bending moment	8
P	N	applied load	8
S	mm	specimen span	6.2
ε_1	—	average strain calculated by measured displacement of upper LVDT	8
ε_2	—	average strain calculated by measured displacement of lower LVDT	8

1) Under preparation. (Stage at the time of publication: ISO/DIS 1920-3:2018.)

2) Under preparation. (Stage at the time of publication: ISO/DIS 1920-4:2018.)

Table 1 *(continued)*

Symbol	Unit	Description	Subclause
ϕ	mm^{-1}	average curvature	8

5 Test specimens

5.1 Geometry

Specimens shall be prisms of square cross-section as shown in Figure 2.

a) The cross-sectional dimensions of the specimen shall be either 150 mm × 150 mm or 100 mm × 100 mm. The side length of the cross-section of the specimen shall be equal to or larger than three times the fibre length.

Specimens with different dimensions provide different test results even if the same FRCC is used. Test results from specimens of various sizes should not be compared.

b) The overall length of the specimen shall not be less than 3,5 *D*.

Key

1 direction of casting

Figure 2 — Test specimen

5.2 Fabrication of specimen

a) The maximum aggregate size shall not be larger than 1/4 of the side length of the cross-section of the specimen.

b) Moulds specified in ISO 1920-3:—, 5.2.1, shall be used.

c) FRCC shall be placed continuously without joints. In case of flowable FRCC, pouring along the axial direction from one end of the mould is recommended. Internal vibrator and compacting rod/bar shall not be used.

d) The dimension tolerance for the specimen cross-section is ±0,5 %.

e) The mass of specimen shall be measured to the nearest 0,05 kg.

f) The number of specimens shall not be less than six. When the number of specimens that do not show separated multiple cracks (see Clause 1) is more than one third of the total number of specimens, this document shall not be applied to that FRCC.

NOTE For FRCCs that do not show separated multiple cracks, see ISO 19044.

5.3 Loading of specimen

a) The specimen shall be subjected to testing immediately after completion of the specified curing procedure.

b) The specimen shall be tested in a position rotated 90° along its longitudinal axis with respect to the casting position.

c) The specimen span shall be 3 D with a tolerance of ±2 %.

6 Test equipment

6.1 Testing machine

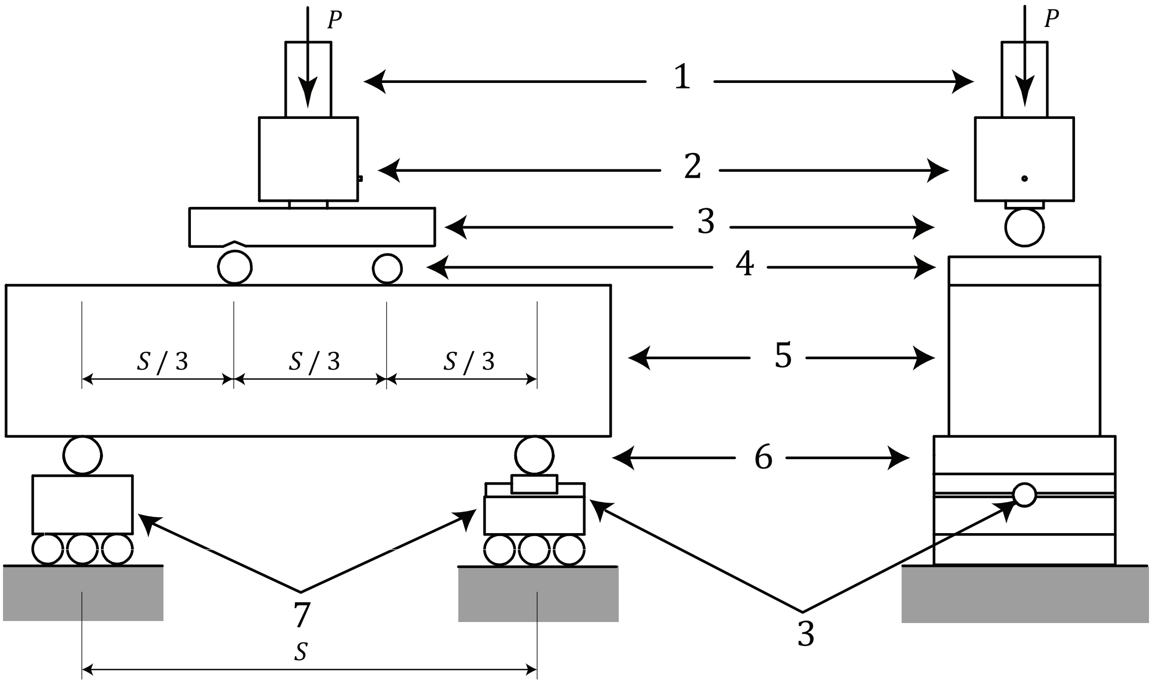
A testing machine complying with ISO 1920-4:—, 4.2.1, shall be used. A testing machine capable of operating in a controlled manner, i.e. producing a constant rate of displacement is also allowable to be used.

6.2 Loading apparatus

The device for applying loads shall consist of two upper rollers (indicated by 4 in Figure 3), two lower rollers (indicated by 6 in Figure 3), and two supports (indicated by 7 in Figure 3). Each roller, except one of the lower ones, shall be capable of being inclined in a plane normal to the longitudinal axis of the test specimen. Cup cone type of roller connections may be used instead of rollers.

NOTE Figure 3 shows a typical example of the loading apparatus.

Both bottom supports should be movable, as the horizontal movement of the specimen is restrained at the loading block. Inserting multiple rods under both supports as shown in Figure 3 is a simple and effective solution for a movable mechanism. In order to ensure the absence of horizontal restraint, it is advisable to press the specimen lightly by hand before applying any load to confirm smooth movement of the specimen in the horizontal direction.



Key

1 machine head
2 load cell
3 round bar
4 upper roller
5 specimen
6 lower roller
7 support

Figure 3 — Example of loading apparatus

6.3 Measuring device for average curvature

The curvature measuring equipment shall consist of two linear variable displacement transducers (LVDTs) and jigs used for fixing LVDTs to the specimen. LVDTs having an accuracy of 1/500 mm or better shall be used for measuring the axial deformation of test specimen.

LVDTs shall be set to measure axial deformation in the constant moment span at positions of 0,15 *D* and 0,85 *D* from the lower surface of the test specimen as shown in Figure 4. The contact length of LVDTs shall be equal to the pure bending span length (*S* / 3). The distance between two LVDTs shall be 0,7 *D*. As shown in Figure 5, the LVDTs shall be set via jigs to allow their rotation during testing when it is likely that such rotation is restricted.

NOTE 1 Figure 6 shows typical examples of the jigs to set LVTDs. Other measuring equipment is applicable if the required accuracy is satisfied.

NOTE 2 Three or more LVDTs can be set to estimate the distribution of average strains.