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Test methods for fibre-reinforced cementitious composites — Load-displacement curve using notched specimen

Méthodes d'essai des composites à base de ciment renforcés par des fibres — Courbe de déplacement de charge utilisant un échantillon entaillé

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Foreword

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

This second edition cancels and replaces the first edition (ISO 19044:2016), which has been technically revised.

The main changes are as follows:

— in Clause 2, the normative reference has been updated;

— in Clause 4, the list of symbols has been updated;

— the legend for Figure 1 has been edited;

— A.7 has been updated.

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.

Test methods for fibre-reinforced cementitious composites — Load-displacement curve using notched specimen

1 Scope

This document specifies the test method for the load-displacement curves of fibre-reinforced cementitious composites (FRCC) by three-point loading of notched prisms. The main purpose of this test is to evaluate the tension softening curve of FRCC.

NOTE 1 Both crack mouth opening displacement (CMOD) and load point displacement (LPD) are specified as the displacement in load-displacement curves, but measurement of both might not be necessary. Either can be selected depending on the purpose of measurement.

NOTE 2 Three-point bending test using notched specimen generally provides higher results than those observed in four-point bending test, in which the fracture occurs at the weakest point of the specimen.

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 1920-3:2019, *Testing of concrete — Part 3: Making and curing test specimens*

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 http://www.iso.org/obp

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

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

Note 1 to entry: Fibres include chemical fibres (metallic fibres, inorganic fibres, synthetic fibres, and so on) and natural fibres.

3.2
ligament
area above the notch subject to fracture

3.3
notch
cut for the initiation of fracture

4 Symbols

Symbol	Unit	Description	Reference
a_0	mm	depth of notch	5.1
b	mm	width of ligament	5.1
D	mm	depth of cross section of specimen	5.1
h	mm	height of ligament	5.1
L	mm	overall length of specimen	5.1
n_0	mm	width of notch	5.1
S	mm	loading span	5.1
t_k	mm	thickness of knife-edge	6.4

5 Test specimen

5.1 Geometry

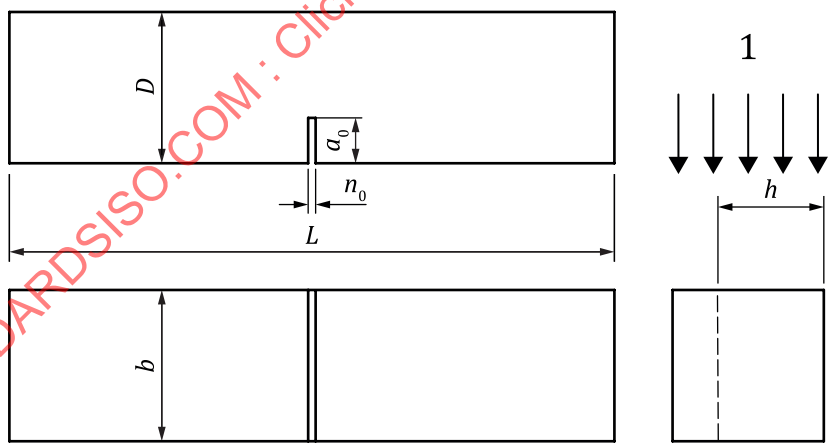
Specimens shall be prisms of square cross section with a notch at the mid-length as shown in Figure 1.

a) The cross sectional size of the specimen shall be fixed with two types for the ease of operating as follows: 150 mm × 150 mm and 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.

The specimens with different dimensions provide different test results even if the same FRCC is used. These test results should not be compared.

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

c) The notch depth (a_0) and notch width (n_0) shall be 0,3 D and not more than 5 mm, respectively.



Key

1 The arrows show the direction of casting.

Figure 1 — 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 1920-3:2019, 5.2.1 shall be used.

c) FRCC shall be placed in one placing sequence without joints. In case of flowable FRCC, pouring toward the axial direction from the one side of the mould is recommended. The internal vibrator and compacting rod/bar shall not be used.

d) The notch shall be cut using a concrete saw when the FRCC has developed sufficient strength.

The notch should be cut in one side that faced the side of the mould. The casting surface becomes vertical one for loading. It is not necessary to cut the edges of the notch to specific forms, as the edge shape scarcely affects the test results.

e) The number of specimens shall be not less than six. The tolerances of specimens are ±0,5 % for a side of section.

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

5.3 Loading of specimen

a) Specimens shall be subjected to testing in a condition immediately after completion of the specified curing procedure.

b) The direction of loading shall be perpendicular to the direction of casting of the specimen.

c) The loading span, S, shall be 3 D. The tolerance of the loading span is ±2 %.

6 Test equipment

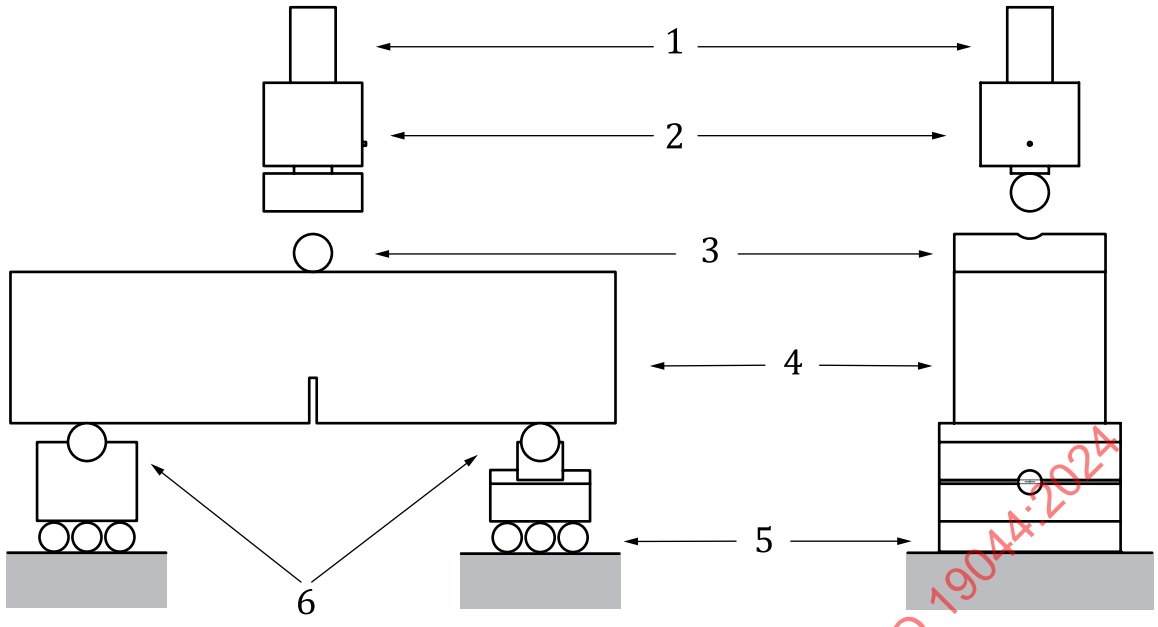
6.1 Testing machine

A testing machine capable of operating in a controlled manner, i.e. producing a constant rate of displacement (CMOD or LPD), and with sufficient stiffness shall be used.

6.2 Loading apparatus

In order to eliminate torsional action on the specimen, the loading block and one of the supports shall be rotatable around their axes in the direction of the specimen axis. Both supports shall be hinged with rollers in order to avoid any restraint on the deformation until the specimen completely ruptures.

Both 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 2 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 specimen
5 roller
6 round bar ϕ = 20 mm to 30 mm

Figure 2 — Loading apparatus

6.3 Measuring device for load

The load shall be measured using a load cell with an accuracy of 1 % of the estimated peak load or better. The load cell shall be fixed to the testing machine.

6.4 Measuring device for CMOD

The CMOD shall be measured using a clip gauge with an accuracy of 1/500 mm or better. If clip gauges cannot be directly attached to the notch, knife-edges are used. The thickness of the knife-edges (t_k) to which the clip gauge is attached shall be not more than 5 mm (Figure 3). If the knife-edges are used, measuring position of CMOD shall be indicated in the test report. Also, if the inverse analysis is conducted, the measuring position should be considered.

Knife-edges, which should be made of metal, should be attached as shown in Figure 3 using an adhesive to ensure bond with the specimen. When wet testing is to be conducted with knife-edges attached to the specimen with an adhesive, the surfaces receiving the knife-edges have to be temporarily dried at the time of adhering. In this case, it is advisable that the portions other than the surfaces receiving the knife-edges be covered with a wet cloth or immersed in water to avoid drying.

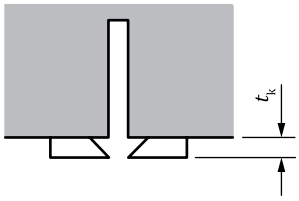
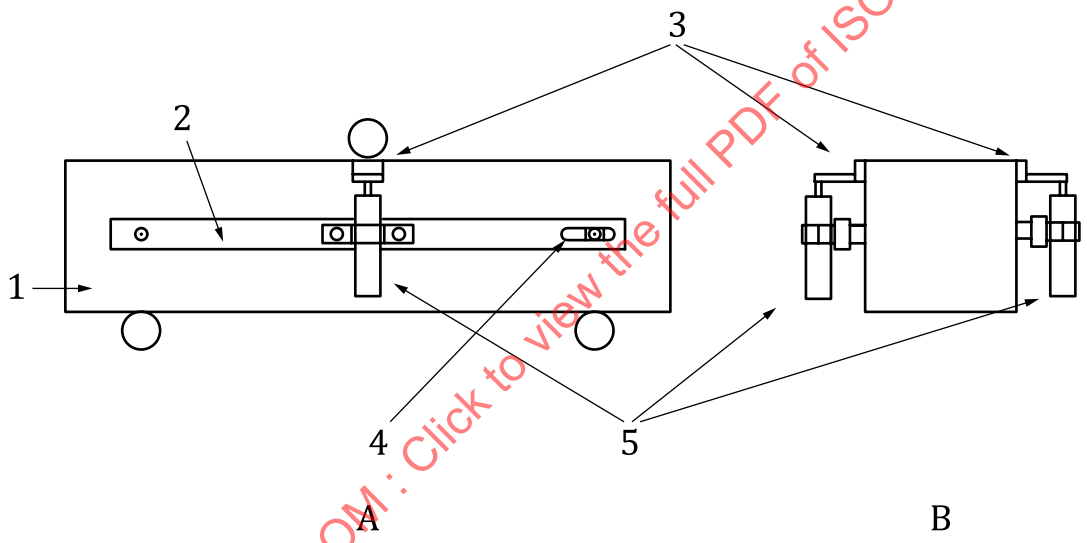


Figure 3 — Knife-edges

6.5 Measuring device for LPD

The LPD shall be measured using displacement transducers as shown in Figure 4. The transducers shall have an accuracy of 1/500 mm or better. Holder frames, made of aluminium or steel bars, shall be used in order to eliminate the rigid-body displacement of the specimen and its deformation due to crushing at the loading and support points. The loose hole shall be made at the one support of the holder frames in order to avoid the restraint on the axial deformation of the specimen. The measuring points shall be, as a rule, on both sides of the specimen directly below the loading point using angles. However, if it is difficult to fix displacement transducers at such points, measurement at the shoulders of the notch near the bottom centre is permitted.



Key

A front view
B side view
1 specimen
2 holder frame
3 angle
4 loose hole
5 displacement transducer

Figure 4 — Measuring system of LPD

7 Test procedure

a) Set the specimen on the loading apparatus so that the notch shall be located on the bottom.

b) Load the specimen continuously and without shock.

c) The CMOD (or LPD) shall be increased at a constant rate of 0,05 mm/min. After the CMOD (or LPD) reach 0,1 mm, the rate may be increased to a constant rate of 0,2 mm/min.

Though it is desirable to keep the loading rate constant from the beginning through the end of testing, it can be increased within the range of not substantially affecting the load-displacement curve, to shorten the testing time, after the post-cracking reductions in the load have settled. The method of such a change in the loading rate shall be reported.

d) Measure the load and CMOD and/or LPD continuously from the beginning through the end of testing. The intervals between readings by a digital measuring device shall be short enough to permit 20 or more readings before the peak load is reached. Testing shall be continued until the CMOD or LPD reaches at least 0,04 D or 0,03 D, respectively. It is desirable to continue testing until the larger CMOD or LPD, when evaluating the fracture properties up to a large deformation.

In the early period of loading during which there is a significant load variation, the values of the load and the corresponding CMOD or LPD need to be recorded at a rate not less than 5 Hz; afterwards, the above rate may be reduced to not less than 1 Hz.

e) When the fracture of the specimen is observed not at ligament, the corresponding test data should be discarded.

f) Measure the width (b) of the broken ligament to the nearest 0,2 mm at two locations and calculate the average to four significant figures.

g) Measure the height (h) of the broken ligament to the nearest 0,2 mm at two locations and calculate the average to four significant figures.

h) Express the load-CMOD curve or load-LPD curve as averages of at least six specimens. To average the load-CMOD curves (or load-LPD curves), calculate the average of the loads on specimens at a given displacement. In this procedure, the intervals between displacements shall be similar to the intervals between measurements specified in d).

8 Calculations

The tension softening curve can be estimated following Annex A.

9 Test report

The test report shall include the following items:

a) FRCC composition;

b) a reference to this document, i.e ISO 19044:2024;

b) type and dimensions of fibre;

c) volume fraction of fibre;

d) curing conditions and history;

e) date of mixing, notching, and loading;

f) type of loading machine;

g) loading span;

h) mass of loading jig;

i) number of specimens;

j) identification of the test specimen;

k) geometry of the specimen;

l) mass of the specimen;

m) height and width of ligament;

n) loading rate;

o) measuring position of CMOD;

p) load-CMOD curve and/or load-LPD curve;

q) tension softening curve.

Annex A
(informative)

Method of estimating tension softening curve

A.1 General

This annex is intended to complement matters related to the provisions of the body text but does not form a portion of the provisions.

This annex specifies a method of estimating a tension softening curve by poly-linear approximation using the data of load-displacement curves obtained from mode I stable failure testing on notched specimens. The tension softening curve determined by this method is a curve that expresses the relationship between the crack mouth opening displacement (CMOD) and the cohesive stress, which is employed for the analysis of mode I concrete fracture by fictitious crack model.

A.2 Load-displacement curve

The load-displacement curve to be used for analysis shall be a load-CMOD curve determined in accordance with this document.

A.3 Estimation of tension softening curve

The tension softening curve shall be estimated by poly-linear approximation. Figure A.1 shows the analysis flow of poly-linear approximation. Because poly-linear approximation includes numerical calculation, a program with confirmed reliability shall be used for the analysis.

An example of the inverse analysis program can be downloaded at following URL:
https://www.jci-net.or.jp/j/jci/study/jci_standard/estimation_frcc.html