
**Fibre-reinforced polymer (FRP)
reinforcement of concrete — Test
methods —**

**Part 2:
FRP sheets**

*Polymère renforcé par des fibres (PRF) pour l'armature du béton —
Méthodes d'essai —
Partie 2: Feuilles en PRF*

Sample Document

get full document from standards.iteh.ai



Sample Document

get full document from standards.iteh.ai



COPYRIGHT PROTECTED DOCUMENT

© ISO 2015

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword	iv
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
3.1 Definitions.....	1
3.2 Symbols.....	3
4 General provision concerning test pieces	5
5 Test method for determining tensile properties	5
5.1 Test pieces.....	5
5.2 Testing machine and measuring devices.....	9
5.3 Test method.....	9
5.4 Calculation and expression of test results.....	10
5.5 Test report.....	11
6 Test method for overlap splice strength	12
6.1 Test pieces.....	12
6.2 Testing machine.....	14
6.3 Test method.....	14
6.4 Calculation and expression of test results.....	15
6.5 Test report.....	15
7 Test method for determining bond properties of FRP sheets to concrete	16
7.1 Test pieces.....	16
7.2 Testing machine and measuring devices.....	21
7.3 Test method.....	21
7.4 Calculation and expression of test results.....	21
7.5 Test report.....	22
8 Test method for direct pull-off strength of FRP sheets with concrete	23
8.1 Test pieces.....	23
8.2 Testing machine and measuring devices.....	25
8.3 Test method.....	25
8.4 Calculation and expression of test results.....	25
8.5 Test report.....	26
9 Test method for freeze/thaw resistance	26
9.1 Test pieces.....	26
9.2 Testing machine and measuring devices.....	26
9.3 Test method.....	27
9.4 Calculation and expression of test results.....	27
9.5 Test report.....	28
10 Test method for exposure to laboratory light sources	29
10.1 Test pieces.....	29
10.2 Testing machine and measuring devices.....	29
10.3 Test method.....	30
10.4 Calculation and expression of test results.....	30
10.5 Test report.....	31
11 Test method for durability	32
11.1 Types of test methods for durability.....	32
11.2 Test piece.....	32
11.3 Test method.....	33
11.4 Calculation and expression of test results.....	34
11.5 Test report.....	34

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document 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 second edition (ISO 10406:2008), which has been technically revised.

ISO 10406 consists of the following parts, under the general title *Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods*:

- *Part 1: FRP bars and grids*
- *Part 2: FRP sheets*

Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods —

Part 2: FRP sheets

1 Scope

This part of ISO 10406 specifies test methods applicable to fibre-reinforced polymer (FRP) sheets for the upgrading of concrete members.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 31-0:1992, *Quantities and units — Part 0: General principles*

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 4892 (all parts), *Plastics — Methods of exposure to laboratory light sources*

ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

3 Terms and definitions

3.1 Definitions

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

3.1.1

accelerated artificial exposure testing machine

machine that creates reproducible standard test conditions to accelerate weathering artificially

3.1.2

ambient temperature

environmental conditions corresponding to the usual atmospheric conditions in laboratories with uncontrolled temperature and humidity

3.1.3

anchorage block

block corresponding to the test block to prevent bond failure of the FRP sheet

Note 1 to entry: Additional FRP sheet circumferentially jackets the block with sheets being tested to provide higher bond strength (in this block).

3.1.4

anchoring portion

end parts of a test piece fitted with anchoring devices to transmit loads from the testing machine to the test portion

3.1.5

bond strength

strength calculated by dividing the maximum load by the effective bond area

3.1.6

concrete block

rectangular block of concrete used to study the bond properties of FRP sheets to concrete

Note 1 to entry: Steel reinforcement or steel bars are embedded in the axial direction at the centre of the cross-sectional area of the concrete block in order to transmit tensile strength. Concrete blocks are made up of a test block and an anchorage block.

3.1.7

conditioning

storage of test pieces at a prescribed temperature and humidity to keep them under identical conditions before testing

3.1.8

coupon test piece

test piece selected from the same lot that is unexposed and subjected to the tensile strength and overlap splice strength tests

3.1.9

effective bond area

area estimated using the effective bond length and the bond width of the FRP sheet

3.1.10

effective bond length

length of the portion in which the bond stress between the FRP sheet and the concrete acts effectively at maximum load before the FRP sheet comes loose from the concrete

3.1.11

fibre bundle

several fibre filaments bound together to form a bundle

3.1.12

fibre mass per unit area

mass of fibre in the direction of reinforcement in dry sheet (fibre sheets before impregnation with resin)

Note 1 to entry: Expressed as mass per square metres.

3.1.13

interfacial fracture energy

amount of energy per unit bond area necessary to produce interfacial fracture

3.1.14

overlap splice strength retention rate

ratio of the overlap splice strength after accelerated artificial exposure or freezing/thawing compared with the overlap splice strength before accelerated artificial exposure or freezing/thawing

Note 1 to entry: The overlap splice strength retention is rate expressed as a percentage.

3.1.15

plate

FRP sheet impregnated with resin from which the test pieces are cut

3.1.16**pull-out strength**

strength calculated by dividing the maximum load by the cross-sectional area of the bond surface of the steel device

3.1.17**steel device**

mechanism made of steel connected to a loading machine to apply tensile force

Note 1 to entry: Adhesive is used to mount the device to the FRP sheet attached to the concrete surface. The shape of the bond surface is either square or circular.

3.1.18**tab**

plate made of fibre-reinforced polymer, aluminium, or any other suitable material bonded to the test piece to transmit loads from the testing machine to the test portion

3.1.19**tensile capacity**

maximum tensile load which the test piece bears during the tensile test

3.1.20**tensile strength retention rate**

ratio of the tensile strength after accelerated artificial exposure or freezing/thawing compared with the tensile strength before accelerated artificial exposure or freezing/thawing

Note 1 to entry: The tensile strength retention rate is expressed as a percentage.

3.1.21**test block**

block used to study the bond properties of FRP sheets

3.1.22**test portion**

part of a test piece that is in between the anchoring portions and is subjected to testing

3.1.23**ultimate strain**

strain corresponding to the tensile capacity

3.1.24**weathering**

physical and chemical changes of material properties due to exposure to sunlight, rain, snow, and other outdoor natural conditions

3.2 Symbols

See [Table 1](#).

Table 1 — Symbols

Symbol	Unit	Description	Reference
A	mm ²	Nominal cross-sectional area (general)	5.4
A _A	mm ²	Nominal cross-sectional area of type A test piece	5.4 , 6.4
A _B	mm ²	Nominal cross-sectional area of type B test piece	5.4 , 6.4
A _s	mm ²	Area of steel device	8.4
b _{av}	mm	Average width of FRP sheet	7.4

Table 1 (continued)

Symbol	Unit	Description	Reference
$b_{t,min}$	mm	Minimum width of test piece	5.4 , 6.4
E_f	N/mm ²	Young's modulus	5.4 , 7.4
f_{au}	N/mm ²	Bond strength	8.4
f_{fu}	N/mm ²	Tensile strength	5.4
$\bar{f}_{fu0}$	N/mm ²	Average value for tensile strength before treating, e.g. freezing and thawing or accelerated artificial exposure	9.4 , 10.4
$\bar{f}_{fu1}$	N/mm ²	Average value for tensile strength after treating, e.g. freezing and thawing or accelerated artificial exposure	9.4 , 10.4
f_{fus}	N/mm ²	Overlap splice strength	6.4
$\bar{f}_{fus0}$	N/mm ²	Average value for overlap splice strength before treating, e.g. freezing and thawing or accelerated artificial exposure	9.4 , 10.4
$\bar{f}_{fus1}$	N/mm ²	Average value for overlap splice strength after treating, e.g. freezing and thawing or accelerated artificial exposure	9.4 , 10.4
F_{au}	N	Maximum load	8.4
F_{last}	N	The load included in the last simultaneously recorded pair of values of the load and the strain when determining the ultimate strain	5.4.5
F_u	N	Tensile capacity	5.4 , 6.4
G_f	N/mm	Interfacial fracture energy	7.4
L_{A1}	mm	Anchoring portion length	5.1.1
L_{A2}	mm	Anchorage thickness	5.1.1
L_{A3}	mm	Anchorage length	5.1.1
L_{end}	mm	Width at both ends	5.1.1
L_{ga}	mm	Gauge length	5.1.1
L_{th}	mm	Thickness	5.1.1
L_{tot}	mm	Total length	5.1.1
l	mm	Effective bond length in test portion of FRP sheet	7.4
N_t	—	Number of fibre bundles in test piece	5.4
n	—	Number of plies of the sheet	7.4
n_u	strands/mm	Number of fibre bundles per unit area of the sheet	5.4
P_{max}	N	Maximum load	7.4
R_{ets}	%	Overlap splice strength retention	9.4
R_{ett}	%	Tensile strength retention	9.4
t	mm	Thickness of sheet, equal to $n \cdot \rho_s / \rho_{sh} \times 10^{-3}$	7.4
ΔF	N	Difference between loads at two points at 20 % and 50 % of tensile capacity	5.4
ρ_s	g/m ²	Fibre mass per unit area of dry sheet	5.4 , 6.4 , 7.4
ρ_{sh}	g/cm ³	Density of dry sheet	5.4 , 6.4 , 7.4
ε_{last}	—	The strain included in the last simultaneously recorded pair of values of the load and the strain when determining the ultimate strain	5.4.5

Table 1 (continued)

Symbol	Unit	Description	Reference
ε_{fu}	—	Difference in strain between the two points used to calculate ΔF	5.4.5
$\Delta\varepsilon$	—	Ultimate strain	5.4
τ_u	N/mm ²	Bond strength	7.4

4 General provision concerning test pieces

Unless otherwise agreed upon, test pieces shall be taken from the sheet in the “as delivered” condition.

For the determination of the mechanical properties in the tensile, bond, and anchorage tests, the test piece may be artificially aged (after straightening, if applicable) depending on the performance requirements of the product.

When a test piece is “aged”, the conditions of the ageing treatment shall be stated in the test report.

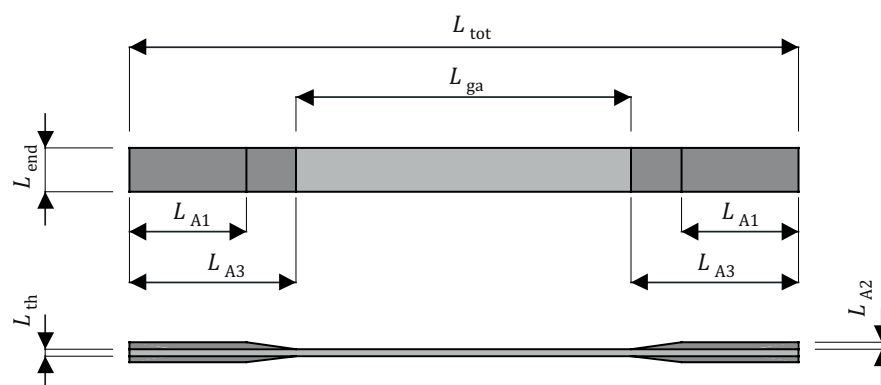
5 Test method for determining tensile properties

5.1 Test pieces

5.1.1 Types and dimensions

Two types of test pieces may be used (see [Figure 1](#) and [Table 2](#)).

- Type A test pieces: Prepare type A test pieces in accordance with the method described in 6.1.2.1 and use them for the general tension test. The shape and the dimensions of type A test pieces are given in [Figure 1](#) and [Table 2](#), respectively.
- Type B test pieces: Prepare type B test pieces in accordance with the method described in 6.1.2.2. These test pieces are suitable for FRP sheets in which the fibre bundles consist of a number of filaments that can be easily separated into individual bundles.



NOTE See [Table 2](#) for definitions of symbols and dimensions.

Figure 1 — Shape of type A and type B test pieces

Table 2 — Dimensions of test pieces

Dimensions in millimetres

Symbol		Dimension for the types of test piece	
		Type A	Type B
L_{tot}	total length	≥ 200	
L_{end}	width at both ends	$12,5 \pm 0,5$	10 to 15
L_{th}	thickness	Recommended not to exceed 2,5	
L_{ga}	gauge length	≥ 100	
L_{A1}	anchoring portion length	≥ 35	
L_{A2}	anchorage thickness	1 to 2	
L_{A3}	anchorage length	≥ 50	
NOTE When the peeling off at tabs and the pull-out in the chuck do not occur, the thickness of the test piece can exceed 2,5 mm. When the thickness of the test piece is less than 2,5 mm and fracture at anchoring section occurs, the specification of the anchoring section should be reconsidered.			

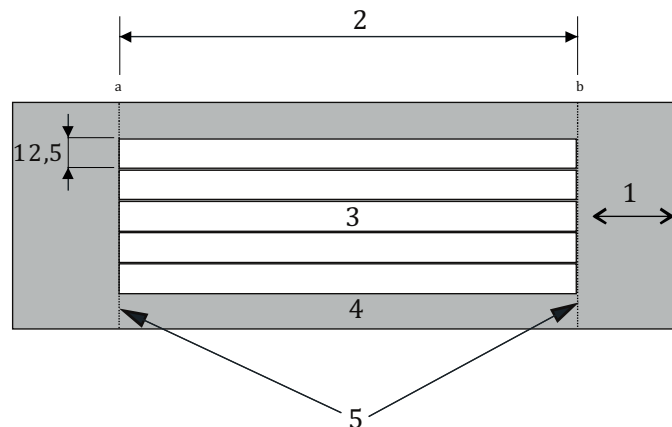
5.1.2 Preparation

5.1.2.1 Type A test pieces

Type A test pieces shall be prepared using the following method.

- Prepare a dry sheet cut to a sufficient length for the test piece.
- Apply the bottom coat of impregnation resin to the separation film and attach the aforementioned sheet, fastening it so that the fibre axis of the sheet is in a straight line.
- Apply the top coat of impregnation resin then smooth the surface so that the thickness of the impregnation resin layer is even, to form a plate. Covering with separation film and smoothing would be best.
- Cure the plate for the prescribed duration considering manufacturer's instructions, then cut in widths of 12,5 mm as shown in [Figure 2](#). The cut length should be at least 200 mm. Use a diamond cutter for cutting.
- Attach the anchorages to the anchorage portions to form the test pieces.
- Prior to testing, the test pieces shall be conditioned as prescribed in [5.1.5](#) considering manufacturer's instructions.

Dimensions in millimetres

**Key**

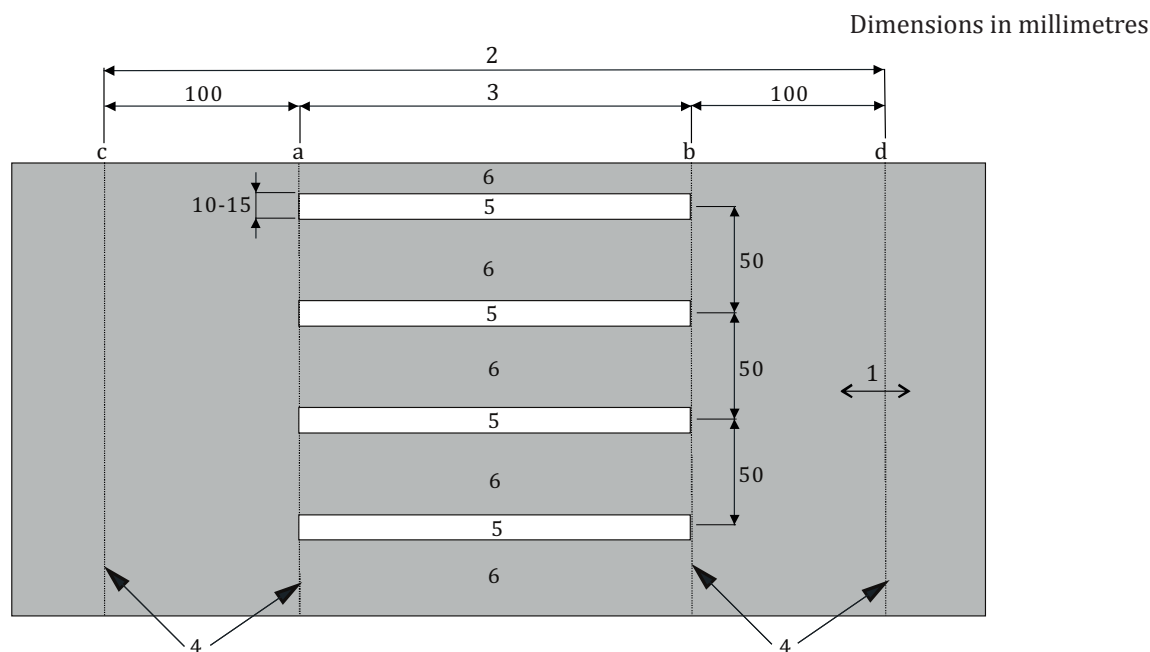
- 1 direction of fibre axis
- 2 section used to prepare test piece: ≥ 200 (area impregnated with resin)
- 3 test piece portion
- 4 cut-away portion
- 5 marking
- a, b Location of the two straight-line marks perpendicular to the fibre axis that define a length of at least 200 mm.

Figure 2 — Dimensions of plate used to prepare type A test pieces

5.1.2.2 Type B test pieces

Type B test pieces shall be prepared using the following method.

- a) Prepare a dry sheet cut to a sufficient length for the test piece. Fasten the sheet so that the fibre axis is in a straight line.
- b) In the centre of the fastened sheet, mark two straight lines (footnotes a and b in [Figure 3](#)) perpendicular to the fibre axis that define a length of at least 200 mm. Mark two other straight lines (footnotes c and d in [Figure 3](#)) approximately 100 mm on either side of the area defined by lines a and b.
- c) Working along the fibre axis between lines c and d, remove one to three fibre bundles from each side of the test piece sections. The width measures 10 mm to 15 mm. When preparing several test pieces from the same FRP sheet, the portions to be used as test pieces should be separated by intervals of at least 50 mm in the direction perpendicular to the fibre axis.
- d) Apply the bottom coat of impregnation resin to the separation film and attach the aforementioned sheet onto the film.
- e) Apply the topcoat of impregnation resin. Then smooth the surface, so that the thickness of the impregnation resin layer is even, to form a plate. Covering with separation film and smoothing would be best.
- f) Cure the plate for the prescribed duration, then cut the fibre bundle portions that are to be the test pieces at widths of 10 mm to 15 mm. The cut length shall be at least 200 mm.
- g) Attach the anchorages to the anchorage portions to form the test pieces.



Key

- 1 direction of fibre axis
- 2 area impregnated with resin: ≥ 400
- 3 section used to prepare test piece: ≥ 200
- 4 marking
- 5 cut-away portion
- 6 test piece portion
- a, b Location of the two straight-line marks perpendicular to the fibre axis that define a length of at least 200 mm.
- c, d Location of the two straight-line marks at least 100 mm on either side of lines a and b.

Figure 3 — Dimensions of plate used to prepare type B test pieces

- h) Prior to testing, condition the test pieces as prescribed in [5.1.5](#) considering manufacturer's instructions.

A tracer thread may be added to uncured, wet-laid material to help identify the fibre direction and to somehow specify how accurately the specimens should be cut from the larger piece of material, specifically with respect to the fibre direction.

5.1.3 Curing of test pieces

Establish the curing period needed to give the test piece the desired strength and cure the test piece considering manufacturer's instructions.

5.1.4 Anchorage portion of test pieces

The anchorage portion of the test piece shall not have a shape that causes the test piece to twist or bend. An anchorage made of fibre-reinforced polymer or aluminium shall be attached to the anchorage portion using resin or adhesive at a suitable pressure so that the thickness of the adhesive layer is constant. The adhesive or resin shall ensure that the adhesive layer does not experience shear fracture before the test piece breaks.