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

**Part 2:
FRP sheets**

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

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 10406-2 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*.

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*

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— Part 2: *FRP sheets*

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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 referenced documents are indispensable for the application 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 31-0:1992, *Quantities and units — Part 0: General principles*
[ISO 10406-2:2008](#)

ISO 291:2008, *Plastics — Standard atmospheres for conditioning and testing*
<https://standards.iteh.ai/standards/iso/9143283-6287-4115-a031-14f50bdf29dd/iso-10406-2-2008>

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*

JIS A 9511, *Preformed cellular plastics thermal insulation materials*

3 Definitions and symbols

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 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 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

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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 the FRP sheets before impregnation with resin

NOTE Expressed as mass per square metre of the FRP sheet.

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 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 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 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
$b_{t,min}$	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}		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}		Anchoring portion length	5.1.1
L_{A2}		Anchorage thickness	5.1.1
L_{A3}		Anchorage length	5.1.1
L_{end}		Width at both ends	5.1.1
L_{ga}		Gauge length	5.1.1
L_{th}		Thickness	5.1.1
L_{tot}		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 FRP sheet	7.4
n_u	strands/mm	Number of fibre bundles per unit area of the FRP 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

Table 1— Symbols (continued)

Symbol	Unit	Description	Reference
t	mm	Thickness of FRP sheet, equal to $n \cdot \rho_S / \rho_{sh}$	7.4
ΔF	N	Difference between loads at two points at 20 % and 60 % of tensile capacity	5.4
ρ_S	g/mm^2	Surface density of the fibre of the FRP sheet	5.4, 6.4, 7.4
ρ_{sh}	g/mm^3	Density of FRP 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
ϵ_{fu}	—	Ultimate strain	5.4.5
$\Delta \epsilon$	—	Difference in strain between the two points used to calculate ΔF	5.4
τ_u	N/mm^2	Bond strength	7.4

4 General provision concerning test pieces

Unless otherwise agreed, test pieces shall be taken from the bar or grid in the “as-delivered” condition.

In cases where test pieces are taken from a coil, they shall be straightened prior to any test by a simple bending operation with a minimum amount of plastic deformation.

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.

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

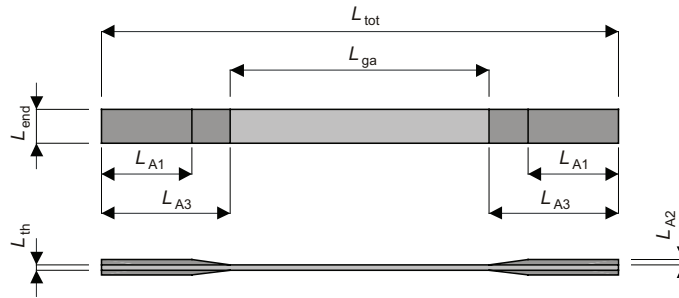
5 Test method for determining tensile properties

5.1 Test pieces

5.1.1 Types and dimensions

Two types of test pieces may be used (see Figure 1 and Table 1):

- a) Type A test pieces: Prepare type A test pieces in accordance with the method described 5.1.2.1 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.
- b) Type B test pieces: Prepare type B test pieces in accordance with the method described in 5.1.2.2. 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.



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	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		

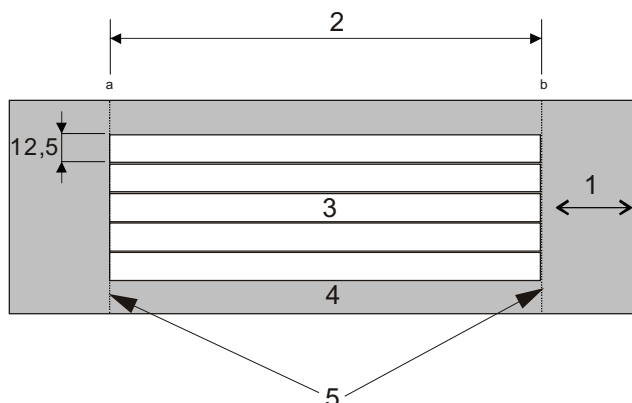
When the peeling-off at tabs and the pull-out in the chuck do not occur, the thickness of the test piece can exceed 2,5 mm. When the thickness of the test piece is less than 2,5 mm and fracture at anchoring section occurs, the specification of the anchoring section should be reconsidered.

5.1.2 Preparation

5.1.2.1 Type A test pieces

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

- a) Prepare an FRP sheet cut to a sufficient length for the test piece.
- b) 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.
- c) 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.
- d) Cure the plate for the prescribed duration, 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.
- e) Attach the anchorages to the anchorage portions to form the test pieces.
- f) Prior to testing, the test pieces shall be conditioned as prescribed in 5.1.5.

**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

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

- a) Prepare an FRP 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 1 to 3 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.