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

### Part 1: FRP bars and grids

*Polymère renforcé par des fibres (PRF) pour l'armature du béton —  
Méthodes d'essai —*

*Partie 1: Barres et grilles en PRF*

Please see the administrative notes on page iii

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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.

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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.

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ISO 10406-1 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*
- *Part 2: FRP sheets*

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

## Part 1: FRP bars and grids

### 1 Scope

This part of ISO 10406 specifies test methods applicable to fibre-reinforced polymer (FRP) bars and grids as reinforcements or pre-stressing tendons in concrete.

### 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 291:2008, *Plastics — Standard atmospheres for conditioning and testing*

ISO 3611, *Micrometer callipers for external measurement*

ISO 4788:2005, *Laboratory glassware — Graduated measuring cylinders*

ISO 6906, *Vernier callipers reading to 0,02 mm*

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, definitions and symbols

#### 3.1 Terms and definitions

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

##### 3.1.1 alkalinity

condition of having or containing hydroxyl ( $\text{OH}^-$ ) ions; containing alkaline substances

NOTE In concrete, the initial alkaline environment has a pH above 13.

##### 3.1.2 anchorage reinforcement

lattice or spiral reinforcing steel or FRP connected with the anchorage and arranged behind it

**3.1.3**

**anchoring section**

end part of a test piece where an anchorage is fitted to transmit loads from the testing machine to the test section

**3.1.4**

**average load**

⟨stress⟩ average of the maximum and minimum repeated load (stress)

**3.1.5**

**bending angle**

angle formed by the straight sections of a test piece on either side of the deflector

**3.1.6**

**bending diameter ratio**

ratio of the external diameter of the deflector surface in contact with the FRP bar, and the nominal diameter of the FRP bar

**3.1.7**

**bending tensile capacity**

tensile load at the moment of failure of the test piece

**3.1.8**

**coefficient of thermal expansion**

average coefficient of linear thermal expansion between given temperatures

**NOTE**

The average of the given temperatures is taken as the representative temperature.

**3.1.9**

**continuous fibre**

general term for continuous fibres of materials such as carbon, aramid and glass

**3.1.10**

**coupler**

device coupling tendons

**3.1.11**

**creep failure capacity**

load causing failure after a specified period of time from the start of a sustained load; in particular, the load causing failure after 1 million hours is referred to as the million-hour creep failure capacity

**3.1.12**

**creep failure strength**

stress causing failure after a specified period of time from the start of a sustained load; in particular, the load causing failure after 1 million hours is referred to as the million-hour creep failure strength

**3.1.13**

**creep failure time**

time between the start of a sustained load and failure of a test piece

**3.1.14**

**creep failure**

failure occurring in a test piece due to a sustained load

**3.1.15**

**creep strain**

differential change in length per unit length occurring in a test piece due to creep



**3.1.16****creep**

time-dependent deformation of an FRP bar subjected to a sustained load at a constant temperature

**3.1.17****deflected section**

section of an FRP bar that is bent and maintained at the required bending angle and bending diameter ratio

**3.1.18****deflector**

device used to maintain the position, alter the bending angle or alleviate the stress concentrations in the FRP bar and which is sometimes installed in the deflected section

**3.1.19****fatigue strength**

maximum repeated stress at which the test piece does not fail at the prescribed number of cycles

**3.1.20****fibre-reinforced polymer****FRP**

composite material, moulded and hardened to the intended shape, consisting of continuous fibres impregnated with a fibre-binding polymer

**3.1.21****frequency**

number of loading (stressing) cycles in 1 s during the test

**3.1.22****FRP bar**

composite material formed into a long, slender structural shape suitable for use as reinforcement in concrete and consisting primarily of longitudinal unidirectional fibres bound and shaped by a rigid polymer resin material

**3.1.23****gauge length**

straight portion along the length of a test piece used to measure the elongation using an extensometer or a similar device

**3.1.124****grid**

two-dimensional (planar) or three-dimensional (spatial) rigid array of interconnected FRP bars that form a contiguous lattice that can be used to reinforce concrete

**3.1.25****load amplitude****load (stress) amplitude**

one-half of the load (stress) range

**3.1.26****load (stress) range**

difference between maximum and minimum repeated load (stress)

**3.1.27****maximum repeated load (stress)**

maximum load (stress) during repeated loading

**3.1.28****maximum tensile force**

maximum tensile load sustained by a test piece during the tensile test

**3.1.29**

**minimum repeated load (stress)**

minimum load (stress) during repeated loading

**3.1.30**

**nominal cross-sectional area**

value obtained upon dividing the volume of the FRP specimen by its length

**3.1.31**

**nominal diameter**

diameter of FRP calculated assuming a circular section

**3.1.32**

**nominal peripheral length**

peripheral length of the FRP that forms the basis for calculating the bond strength and that shall be determined separately for each FRP

**3.1.33**

**number of cycles**

number of times the repeated load (stress) is applied to the test piece

**3.1.34**

**relaxation**

**stress relaxation**

time-dependent decrease in load in an FRP held at a given constant temperature with a prescribed initial load applied and held at a given constant strain

**3.1.35**

**relaxation rate**

percentage reduction in load relative to the initial load after a given period of time, under a fixed strain

NOTE In particular, the relaxation value after 1 million hours (approximately 114 years) is referred to as the hundred-year relaxation rate.

**3.1.36**

**repeated load (stress)**

load (stress) alternating cyclically between fixed maximum and minimum values

**3.1.37**

**S-N curve**

curve plotted on a graph with repeated stress on the vertical axis and the number of cycles to fatigue failure on the horizontal axis

**3.1.38**

**tendon, FRP**

resin-bound construction made of continuous fibres in the shape of a tendon used to reinforce concrete uniaxially

NOTE Tendons are usually used in pre-stressed concrete.

**3.1.39**

**thermo-mechanical analysis**

**TMA**

method for measuring deformation of a material as a function of either temperature or time, by varying the temperature of the material according to a calibrated programme, under a non-vibrating load

**3.1.40**

**TMA curve**

(TMA) graph with temperature or time represented on the horizontal axis and deformation on the vertical axis

**3.1.41****ultimate strain**

strain corresponding to the maximum tensile force

**3.2 Symbols**

See Table 1.

**Table 1 — Symbols**

Symbol	Unit	Description	Reference
$A$	mm <sup>2</sup>	Nominal cross-sectional area of test piece	5.3, 6.4
$D$	mm	Nominal diameter	5.3
$E$	N/mm <sup>2</sup>	Young's modulus	6.4
$F_u$	N	Maximum tensile force	6.4
$f_u$	N/mm <sup>2</sup>	Tensile strength	6.4
$\varepsilon_u$	—	Ultimate strain	6.4
$\Delta F$	N	Difference between loads at 20 % and 50 % of maximum tensile force	6.4
$\Delta \varepsilon$	—	Strain difference between $\Delta F$	6.4
$\tau$	N/mm <sup>2</sup>	Bond stress	7.4
$P$	N	Tensile load in the pull-out test	7.4
$u$	mm	Nominal peripheral length of test piece	7.4
$l$	mm	Bonded length	7.4
$Y$	%	Relaxation rate	9.5.2
$t$	h	Time	9.5.2
$k_a$	—	Empirical constant	9.5.2
$k_b$	—	Empirical constant	9.5.2
$R_{\Delta m}$	%	Mass loss ratio	
$V_o$	mm <sup>3</sup>	Volume of water in the measuring cylinder	5.3
$V_s$	mm <sup>3</sup>	Volume of the sum total of water and test piece	5.3
$l_o$	mm	Length of test piece	5.3
$m_o$	g	Mass before immersion	11.4
$L_o$	mm	Length before immersion	11.4
$m_1$	g	Mass after immersion	11.4
$L_1$	mm	Length after immersion	11.4
$R_{et}$	%	Tensile capacity retention rate	11.5.2
$F_{u1}$	N	Tensile capacity before immersion	11.5.2
$F_{u0}$	N	Tensile capacity after immersion	11.5.2
$R_{Yc}$	—	Creep load ratio	12.6.3
$\tau_s$	N/mm <sup>2</sup>	Shear stress	13.5.2
$P_s$	N	Shear failure load	13.5.2

Table 1 — Symbols (continued)

Symbol	Unit	Description	Reference
$\alpha_{sp}$	1/°C	Coefficient of thermal expansion	15.4.1
$\Delta L_{spm}$	$\mu$	Difference in length of test piece between temperatures $T_1$ and $T_2$	15.4.1
$\Delta L_{refm}$	$\mu$	Difference in length of specification test piece for length calibration between temperatures $T_1$ and $T_2$	15.4.1
$L_0$	m	Length of test piece at room temperature	15.4.1
$T_2$	°C	Maximum temperature for calculation of coefficient of thermal expansion (normally 60°C)	15.4.1
$T_1$	°C	Minimum temperature for calculation of coefficient of thermal expansion (normally 0 °C)	15.4.1
$\alpha_{set}$	1/°C	Coefficient of thermal expansion calculated for specification test piece for length calibration between temperatures $T_1$ and $T_2$	15.4.1

#### 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.

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

#### 5 Test method for cross-sectional properties

##### 5.1 Test pieces

###### 5.1.1 Preparation of test pieces

Test pieces shall be cut to a predetermined length and finished flat at their cut end from the mother material (FRP) for tensile test.

###### 5.1.2 Length of test pieces

The length of test pieces shall be 100 mm when approximate nominal diameter is 20 mm or less, and shall be 200 mm when approximate diameter is over 20 mm.

###### 5.1.3 Number of test pieces

The number of test pieces is at least three, taken from the mother material of the same lot.