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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

Reference number
ISO 10406-1:2008(E)

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Foreword

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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*

INTERNATIONAL STANDARD **ISO 10406-1:2008(E)**

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 (OH^-) ions; containing alkaline substances

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

3.1.2
anchorage reinforcement
latticed 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^2	Nominal cross-sectional area of test piece	5.3, 6.4
D	mm	Nominal diameter	5.3
E	$\mathrm{N/mm}^2$	Young's modulus	6.4
F_u	N	Maximum tensile force	6.4
f_u	$\mathrm{N/mm}^2$	Tensile strength	6.4
ε_u	—	Ultimate strain	6.4
ΔF	N	Difference between loads at 20 % and 50 % of maximum tensile force	6.4
$\Delta\varepsilon$	—	Strain difference between ΔF	6.4
τ	$\mathrm{N/mm}^2$	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
$R_{\Delta\mathrm{m}}$	%	Mass loss ratio	
V_o	mm^3	Volume of water in the measuring cylinder	5.3
V_s	mm^3	Volume of the sum total of water and test piece	5.3
l_o	mm	Length of test piece	5.3
m_0	g	Mass before immersion	11.4
L_0	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
τ_s	$\mathrm{N/mm}^2$	Shear stress	13.5.2
P_s	N	Shear failure load	13.5.2

Table 1 — Symbols (*continued*)

Symbol	Unit	Description	Reference
α_{sp}	1/°C	Coefficient of thermal expansion	15.4.1
ΔL_{spm}	μ	Difference in length of test piece between temperatures T_1 and T_2	15.4.1
ΔL_{refm}	μ	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
α_{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.

5.2 Test method

The test procedure is as follows.

a) Measure the length of the test piece using the vernier callipers in accordance with ISO 6906. Measure a part and record the result to three places; round off the three averaged values to one place after the decimal point. Take this as the length of the test piece.

b) Measure the volume of the test piece using a measuring cylinder in accordance with ISO 4788:2005, type 1a or 1b (class A or class B), according to the approximate diameter of the test piece. Table 2 shows the relationship between the approximate diameter of the test piece and the capacity of the measuring cylinder. When two capacities are listed, choose the smaller-capacity cylinder for that range.

c) Add the proper quantity of water to the measuring cylinder and measure the volume. When the test piece is in the measuring cylinder, the water should cover the test piece and the top of the water shall be in the range of scale.

NOTE If air bubbles are generated on the surface of the test piece, which can cause an error of measurement, a surface-tension-reducing solvent, such as ethanol, can be added to the water for the purpose of controlling the generation of air bubbles.

d) Insert the test piece into the measuring cylinder and measure the volume of the combined water and the test piece.

e) The test temperature shall be within the range of 15 °C to 25 °C.

Table 2 — Relationship between the approximate diameter of test piece and the capacity of measuring cylinder

Approximate diameter of test piece mm	Capacity of measuring cylinder ml
under 10	10 or 20
11 to 13	25
14 to 20	50 or 100
21 to 25	100
over 25	300 or 500

5.3 Calculations

Calculate the nominal cross-sectional area, A, of the test piece from Equation (1) and round off to one place after the decimal point:

$$A = \frac{V_\text{s} - V_\text{o}}{l_\text{o}} \tag{1}$$

where

V_s is the volume of the sum total of water and test piece, expressed in cubic millimetres;

V_o is the volume of water in the measuring cylinder, expressed in cubic millimetres;

l_o is the length of the test piece, expressed in millimetres.

NOTE The nominal cross-sectional area includes the area of surface-bonded sand particles, surface-bonded transverse wraps and other non-load-bearing areas.