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Introduction

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 10406-1

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

Part 1: FRP bars

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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.

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).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document 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*.

Introduction

Fiber Reinforced Polymer (FRP) bars, renowned for their high strength, lightweight nature, excellent bond behaviour, and superior durability, serve a pivotal role in reinforcing new constructions and rehabilitating existing reinforced concrete structures. As the global use of FRP bars continues to expand, the need for standardized test methods has become paramount. Unlike steel, FRP bars exhibit anisotropic behaviour and their performance is influenced by the type of fibres, resin matrix, and manufacturing processes. As such, rigorous and consistent test methods are essential to accurately evaluate the physical properties, mechanical properties, long-term durability, and reliability of FRP bars in various environmental and loading conditions.

This standard provides a comprehensive framework for evaluating the physical properties, mechanical properties, durability, and long-term performance of FRP bars. It aims to promote uniformity in test methods globally, thereby ensuring consistency in product quality and facilitating international trade. By establishing these test methods, this standard supports engineers, manufacturers, and regulators in the design, production, and certification of FRP reinforcement systems for safe and sustainable infrastructure.

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

Part 1: FRP bars

1 Scope

This document specifies test methods application to fiber-reinforced polymer (FRP) bars as reinforcement or pre-stressing tendons in concrete, including physical, mechanical, durability, and long-term properties.

FRP bars in this standard are made of fibre and resin matrix. Types of fibres are aramid fibre, basalt fibre, carbon fibre or glass fibre. The matrix includes thermosetting resins, such as vinylester, unsaturated polyester resins, as well as thermoplastic resins, including polypropylene, polyamides, and polymethyl methacrylate.

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. Members of ISO and IEC maintain registers of currently valid International Standard.

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

ISO 3611, *Geometrical product specifications (GPS) — Dimensional measuring equipment — Design and metrological characteristics of micrometers for external measurements*

ISO 4788, *Laboratory glassware — Graduated measuring cylinders*

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

ISO 13385-1, *Geometrical product specifications (GPS) — Dimensional measuring equipment — Part 1: Design and metrological characteristics of callipers*

3 Terms, definition, and symbols

3.1 Terms and definition

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

alkalinity

condition of having or containing hydroxyl (OH-) ions; containing alkaline substances

Note 1 to entry: In concrete, the initial alkaline environment has a pH above 13.

3.1.2

anchorage reinforcement

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

3.1.3

anchorage 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 1 to entry: 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, glass, and basalt

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

Note 1 to entry: 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

Note 1 to entry: 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 a FRP grid subjected to a sustained load at a constant temperature

3.1.17

deflected section

section of a FRP bar which 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; 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 fibre impregnated with a fibre-binding polymer

3.1.21

FRP bar

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

3.1.22

fibre volume fraction

the ratio of the volume of fibres to the volume of the composite

3.1.23

frequency

number of loading (stressing) cycles in one second during the test

3.1.24

gauge length

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

3.1.25

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

minimum repeated load (stress)

minimum load (stress) during repeated loading

3.1.29

nominal cross-sectional area

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

3.1.30

nominal diameter

diameter of FRP calculated assuming a circular section

3.1.31

nominal peripheral length

peripheral length of the FRP, which forms the basis for calculation of bond strength and shall be determined separately for each FRP

3.1.32

number of cycles

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

3.1.33

relaxation (stress relaxation)

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

3.1.34

relaxation rate

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

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

3.1.35

repeated load (stress)

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

3.1.36

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

3.1.37

tendon, FRP

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

Note 1 to entry: Tendons are usually used in prestressed concrete

3.1.38

thermomechanical 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 program, under a non-vibrating load

3.1.39

TMA curve

in the context of TMA, a graph with temperature or time represented on the horizontal axis, and deformation on the vertical axis

3.1.40

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	5.1.3 , 6.1.5
D	mm	Nominal diameter	5.1.3
E	N/mm ²	Young's modulus	6.1.5
$P_{\max}$	N	Maximum tensile load	6.1.5
f_u	N/mm ²	Tensile strength	6.1.5
ε_u	—	Ultimate strain	6.1.5
ΔP	N	Difference between loads at 20 % and 50 % of maximum tensile load	6.1.5
$\Delta \varepsilon$	—	Strain difference between ΔP	6.1.5
τ_{bu}	N/mm ²	Bond strength	6.2.4
τ_{su}	N/mm ²	Shear strength (N/mm ²)	6.4.5
$P_{b\max}$	N	Maximum pull-out load	6.2.4
P_{su}	N	Shear failure load (N)	6.4.5
u	mm	Nominal peripheral length of test piece	6.2.4
l_b	mm	Bonded length	6.2.4
Y	%	Relaxation rate	8.1.5
t	h	Time	8.1.5
a	—	Empirical constant	8.1.5
b	—	Empirical constant	8.1.5
V_o	mm ³	Volume of water in the measuring cylinder	5.1.3
V_s	mm ³	Volume of the sum total of water and test piece	5.1.3
l_o	mm	Length of test piece	5.1.3
M_f	—	Fibre content of FRP bar	5.2.6
m_1	g	Initial mass of the dry boat or crucible	5.2.6
m_2	g	Initial mass of the boat or crucible plus dried specimen	5.2.6
m_3	g	Final mass of the boat or crucible plus residue after calcination	5.2.6
W_0	g	Mass before immersion	7.1.3
L_0	mm	Length before immersion	7.1.3
W_1	g	Mass after immersion	7.1.3
L_1	mm	Length after immersion	7.1.3
R_{et}	%	Tensile capacity retention rate	7.1.5
F_{u1}	N	Tensile capacity before immersion	7.1.5
F_{u0}	N	Tensile capacity after immersion	7.1.5
Y_c	—	Creep load ratio	8.3.6
f_r	N/mm ²	Million-hour creep rupture strength	8.3.6
F_r	N	Million-hour creep rupture capacity	8.3.6
α_{sp}	1/°C	Coefficient of thermal expansion	5.3.4
ΔL_{spm}	mm	Difference in length of test piece between temperatures T_1 and T_2	5.3.4
ΔL_{refm}	mm	Difference in length of specifications test piece for length calibration between temperatures T_1 and T_2	5.3.4
L_0	mm	Length of test piece at room temperature	5.3.4

Table 1 (continued)

Symbol	Unit	Description	Reference
T_2	°C	Maximum temperature for calculation of coefficient of thermal expansion (normally 60 °C)	5.3.4
T_1	°C	Minimum temperature for calculation of coefficient of thermal expansion (normally 0 °C)	5.3.4
α_{set}	1/°C	Coefficient of thermal expansion calculated for specifications test piece for length calibration between temperatures T_1 and T_2	5.3.4

4 General provision concerning test pieces

Unless otherwise agreed, test pieces shall be taken from the bar in the 'as-delivered' condition.

In cases when test pieces are taken from a coil, the test piece shall be straightened prior to any test by 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 physical properties

5.1 Cross-sectional area

5.1.1 Test pieces

5.1.1.1 Preparation of test pieces

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

5.1.1.2 Length of test pieces

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

5.1.1.3 Number of test pieces

The number of test pieces is five from the mother material of the same lot at least.

5.1.2 Test procedure

The test procedure is as follows:

- The length of the test piece is measured using the vernier callipers specified to ISO 13385-1. A measurement part is made into three places; the three average value rounds off to one figure below a decimal point; it is the length of test piece.
- The volume of the test piece is measured using the measuring cylinder specified to ISO-4788 according to approximate diameter of test piece. [Table 2](#) shows the relationship between approximate diameter of test piece and capacity of measuring cylinder. When there are two or more capacities, the minimum capacity cylinder in the range that can be measured shall be chosen.