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

Part 4: FRP grids

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Foreword

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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 document 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*.

This first edition cancels and replaces the second edition (ISO 10406-1:2015) which has been technically revised.

The main changes are as follows:

— inclusion of thermoplastic resin for FRP grids;

— fibre volume fraction testing and single-lap shear bond test methods have been added;

— tensile performance, alkali resistance, and pull-off bond test methods are modified;

— test method for performance of anchorages and couplers, test method for transverse shear strength, and test method for flexural tensile properties have been deleted.

A list of all parts in the ISO 10406 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Fibre Reinforced Polymer (FRP) grids, renowned for their high strength, lightweight nature, excellent bond behaviour, and superior durability, serve a pivotal role in rehabilitating existing RC structures and reinforcing new constructions. Incorporating FRP grids effectively within structures, it becomes imperative to comprehensively understand involves a comprehensive understanding of their physical properties, mechanical characteristics, long-term performance, durability, and bond capabilities. This understanding is crucial to ensures that structures reinforced or constructed with FRP grids meet the stringent design requirements.

However, the prevalent testing methods for FRP bars or sheets, as outlined in existing specifications, are insufficient in adequately accounting for the spatial bidirectional characteristics inherent in FRP grids. Therefore, the need arises to develop an internationally recognized standard that specifically delineates testing methodologies tailored for FRP grids. This document aims to establish a framework for testing procedures that consider the distinctive spatial bidirectional properties of these grids. Additionally, the document provides essential material properties data required for structural design, offering engineers and designers a reliable basis for incorporating FRP grids into their projects. By formulating a document for testing FRP grids, we endeavor to fill the existing gap in methodologies and facilitate a more accurate assessment of their performance. This document not only enhances the reliability of structural designs utilizing FRP grids but also promotes their wider and more efficient use in construction projects worldwide.

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

Part 4: FRP grids

1 Scope

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

FRP grids in this document can be used for rehabilitating existing reinforced concrete (RC) structures and reinforcing new constructions.

FRP grids in this document are made of fibre and resin matrix. The 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.

FRP grids in this document are a rigid array of interconnected FRP bars, and do not include fibre textile and fabric with a mesh type.

In this document, durability refers to alkali resistance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 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 291:2008, *Plastics — Standard atmospheres for conditioning and testing*

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*

ISO 1172:2023, *Textile-glass-reinforced plastics — Prepregs, moulding compounds and laminates — Determination of the textile-glass and mineral-filler content using calcination methods*

ISO 80000-1:2022, *Quantities and units — Part 1: General*

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

3.1.3
average load
average of the maximum and minimum repeated load

3.1.4
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.

3.1.5
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.

3.1.6
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.

3.1.7
creep failure time
time between the start of a sustained load and failure of a test piece

3.1.8
creep failure
failure occurring in a test piece due to a sustained load

3.1.9
creep strain
differential change in length per unit length occurring in a test piece due to creep

3.1.10
creep
time-dependent deformation of a FRP grid subjected to a sustained load at a constant temperature

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3.1.11
fatigue strength
maximum repeated stress at which the test piece does not fail at the prescribed number of cycles

3.1.12
fibre-reinforced polymer
FRP
composite material, moulded and hardened to the intended shape, consisting of continuous fibre impregnated with a fibre-binding polymer

3.1.13
fibre-reinforced polymer grid
FRP grid
two-dimensional (planar) or three-dimensional (spatial) rigid array of interconnected FRP bars that form a continuous lattice that can be used to reinforce concrete

3.1.14
fibre-reinforced polymer grid segment
FRP grid segment
a strip of single or multiple strands of fibres that are impregnated and solidified with resin and arranged in parallel along the warp or weft direction

3.1.15
fibre area of grid segment
fibre area on the cross section of grid segment

3.1.16
fibre volume fraction
the ratio of the volume of fibres to the volume of the composite

3.1.17
frequency
number of loading cycles in one second during the test

3.1.18
gauge length
straight portion along the length of a test piece used to measure the elongation using an extensometer, or a similar device

3.1.19
load amplitude
one-half of the load range

3.1.20
load range
difference between maximum and minimum repeated load

3.1.21
maximum repeated load
maximum load during repeated loading

3.1.22
minimum repeated load
minimum load during repeated loading

3.1.23
nominal cross-sectional area
value obtained upon dividing the volume of the FRP specimen by its length

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3.1.24
nominal perimeter
peripheral length of the FRP grid segment

Note 1 to entry: The peripheral length of the FRP grid segment forms the basis for calculation of bond strength and shall be determined separately for each grid segment.

3.1.25
number of cycles
number of times the repeated load is applied to the test piece

3.1.26
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

3.1.27
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.

3.1.28
repeated load
load alternating cyclically between fixed maximum and minimum values

3.1.29
S-N curve
plotted on a graph with repeated stress on the vertical axis and the number of cycles to fatigue failure on the horizontal axis

3.1.30
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 program, under a non-vibrating load

3.1.31
thermo mechanical analysis curve
TMA curve
graph, in the context of TMA, with temperature or time represented on the horizontal axis, and deformation on the vertical axis

3.1.32
ultimate strain
strain corresponding to the tensile strength

3.2 Symbols

See Table 1.

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Table 1 — Symbols

Symbol	Unit	Description	Reference
A	mm^2	Nominal cross-sectional area of test piece	5.1, 6.1, 8.3
A_f	mm^2	Fibre area of grid segment	6.1, 8.3
b_{av}	mm	Average bond width of embedded FRP grid	9.2
E	N/mm^2	Young's modulus calculated based on cross-sectional area	6.1, 9.2
E_f	N/mm^2	Young's modulus calculated based on fibre area	6.1, 9.2
f_{fu}	N/mm^2	Tensile strength calculated based fibre area	6.1
f_u	N/mm^2	Tensile strength calculated based cross-sectional area	6.1
F_r	N	Million-hour creep rupture capacity	8.3
F_u	N	Maximum tensile force	6.1
F_{u0}	N	Tensile capacity befor immersion	7.1
F_{u1}	N	Tensile capacity after immersion	7.1
G_f	N/mm	Interfacial fracture energy calculated based on the cross section of FRP grid	9.2
G_{ff}	N/mm	Interfacial fracture energy calculated based on the fibre section of FRP grid	9.2
k_a		Empirical constant	8.1, 8.3
k_b		Empirical constant	8.1, 8.3
K	N	Tensile rigidity calculated based on cross-sectional area	6.1
K_f	N	Tensile rigidity calculated based on fibre area	6.1
l	mm	Bonded length for pullout test	9.1
l_0	mm	Length of test piece	5.1
l_e	mm	Effective bond length of embedded FRP grid	9.2
L	mm	Length of test piece at room temperature	5.3
L_0	mm	Length before immersion	7.1
L_1	mm	Length after immersion	7.1
m	g	Initial mass, in grams, of the dry boat or crucible	5.2
m_0	g	Mass before immersion	7.1
m_1	g	Mass after immersion	7.1
m_2	g	The initial mass, in grams, of the boat or crucible plus dried specimen	5.2
m_3	g	The final mass, in grams, of the boat or crucible plus residue after calcination	5.2
M_f	g	Fibre content of FRP grid	5.2
P	N	Tensile load in the pullout test	9.1
P_{max}	N	Maximum load in the single-lap shear test	9.2
P_r	N	Specified time creep rupture capacity	8.3
R_{et}	%	Tensile capacity retention rate	7.1
R_{Yc}		Creep load ratio	8.3
$R_{\Delta m}$	%	Rate of mass change	7.1
t	hour	Time	8.1, 8.3
t_e	mm	Equivalent width of n FRP grid segments based on cross-section	9.2
t_{fe}	mm	Equivalent width of n FRP grid segments based on fibre section	9.2
T_1	°C	Minimum temperature for calculation of coefficient of thermal expansion (normally 0 °C)	5.3
T_2	°C	Maximum temperature for calculation of coefficient of thermal expansion (normally 60 °C)	5.3
u	mm	Nominal perimeter of every embedded FRP grid segment	9.1
V_0	mm^3	Volume of water in the measuring cylinder	5.1
V_f	%	Fibre volume fraction	5.2

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