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Performance guidelines for design of concrete structures using fibre-reinforced polymer (FRP) materials

Lignes directrices de performance pour la conception des structures en béton utilisant des polymères renforcés de fibres (PRF)

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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 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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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*.

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.

This second edition cancels and replaces the first edition (ISO 14484:2013), which has been technically revised. The main changes compared to the previous edition are as follows:

— the scope of the document now extends from concrete structures with the sole use of FRP materials to those with the combined use of FRP materials and steel reinforcement;

— the compressive strength of FRP materials is now allowed to be accounted for in design; and

— the creep-rupture and fatigue limit states of FRP materials have been specified.

Introduction

Continuous fibre-reinforced polymer (FRP) materials are widely applied to concrete structures. FRP materials have many advantages, such as a high strength/weight ratio and immunity to corrosion. FRP materials are available in a variety of geometries, including rod, grid, plate, sheet, strand, etc.

This document describes the general performance requirements for concrete structures with the use of FRP materials. This document is an umbrella document with general provisions and guidelines and lists the regional consensus guidelines/standards that are deemed to satisfy this document. Regional guidelines/standards are generally more prescriptive in nature and vary somewhat from region to region.

This document is intended to provide wide latitude in terms of general requirements for performance verification and assessment of concrete structures with the use of FRP materials. It is meant to be used in conjunction with sound engineering judgment.

Performance guidelines for design of concrete structures using fibre-reinforced polymer (FRP) materials

1 Scope

This document provides general principles for the verification and assessment of the performance of concrete structures with the applications of different fibre-reinforced polymer (FRP) systems varying from internal FRP reinforcements/tendons, external FRP tendons, externally bonded FRP sheets/plates, to near-surface mounted FRP reinforcement. It can be used for the international harmonization of the design of un-reinforced, conventionally reinforced, and pre-stressed concrete structures with the use of the above-mentioned FRP systems.

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 2394, *General principles on reliability for structures*

ISO 10406-1, *Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 1: FRP bars and grids*

ISO 10406-2, *Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 2: FRP sheets*

ISO 19338, *Performance and assessment requirements for design standards on structural concrete*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19338, ISO 10406-1, ISO 10406-2, and ISO 2394 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
bonding
attachment between fibre-reinforced polymer and substrates

3.2
concrete substrate
concrete or any cementitious material used to repair or replace the original concrete

Note 1 to entry: The substrate can consist entirely of original concrete, entirely of repair materials, or of a combination of original concrete and repair materials.

3.3
debonding
separation at the interface between the substrate and the near-surface mounted or externally bonded fibre-reinforced polymer materials

3.4
fibre-reinforced polymer material
FRP material
assembly of dissimilar materials with a polymeric matrix and continuous fibre reinforcement of aramid, carbon, glass, etc.

3.5
near-surface mounted fibre-reinforced polymer reinforcement
near-surface mounted FRP reinforcement
fibre-reinforced polymer bar or strip which is bonded inside a groove near the surface of a structural component

3.6
fibre-reinforced polymer plate
FRP plate
single or multiple layers of fabric or mat reinforcement bound together in a resin matrix, precured prior to application

3.7
fibre-reinforced polymer sheet
FRP sheet
dry, flexible component which consists of continuous fibres aligned in one or more directions and held together in-plane to create a ply of finite width and length, and is used in wet lay-up systems

4 Design basics

4.1 General

Concrete structures with FRP materials include concrete structures with the sole use of FRP materials and those with the combined use of FRP materials and steel reinforcement.

Design of concrete structures with FRP materials should consider safety, serviceability, and restorability during service life. Where applicable, limit states caused by fire, seismic actions, or other extreme loading or actions (e.g. impact and fatigue) should also be appropriately considered, according to the intended applications of FRP materials (i.e. as the strengthening layer or the internal reinforcement). In addition to the above, costs should also be taken into consideration.

Suitable analysis should be performed to verify that the performance requirements for concrete structures with FRP materials in terms of limit states such as serviceability limit states (SLS) and ultimate limit states (ULS) in accordance with ISO 2394 are satisfied.

4.2 Design methodology

A design methodology for concrete structures with FRP materials should be based on quantitative performance evaluation at the limit states. A rational method should be adopted for analysing each limit state.

Design of concrete structures with FRP materials should consider the linear elastic material properties of FRP and the properties of bond, if available, between the FRP and concrete, based on quantitative performance evaluation at the ultimate limit states.

5 Properties of materials

5.1 Properties of concrete and steel

Properties of concrete and steel should be determined in accordance with those specified for general structural concrete in ISO 19338.

In the case of upgrading existing concrete structures with FRP materials, the strengths of concrete and steel should be determined with consideration of the in situ conditions, such as measured material and geometric properties of the existing concrete structures, instead of their material strength values used in the original design.

5.2 Properties of FRP materials

5.2.1 General

The FRP materials used for concrete structures should be those whose quality and performance characteristics have been confirmed to be compatible with environmental conditions under which the structure will be exposed.

The characteristics of FRP materials should be defined in general conformance with reliability-based design requirements.

The elastic moduli of FRP materials deviate significantly from that of steel reinforcement depending on the types of fibre used, such as carbon, aramid, glass or basalt, and the fibre volumetric ratio.

The compressive strength of FRP materials should be generally ignored in design unless specified otherwise.

If necessary, the temperature-sensitive characteristics of FRP materials should be appropriately considered in design, with attention to its possible strength and stiffness loss at elevated temperatures.

An environmental reduction factor should be introduced to account for the environmental effect on the strength of FRP materials during the expected service life of the structure.

FRP materials shall be designed against creep-rupture under sustained loads unless otherwise noted.

FRP materials shall be designed against fatigue under cyclic loading unless otherwise noted.

5.2.2 FRP bars, grids, and plates

Properties of FRP bars, grids, and plates should be determined in accordance with ISO 10406-1.

5.2.3 FRP sheets

Properties of FRP sheets should be determined in accordance with ISO 10406-2.

5.2.4 Other FRP systems

Properties of other types of FRP systems should be determined based on appropriate test methods, with consideration to their intended applications.

5.3 Resins

Mechanical and physical properties of resins (matrix for fibres and bonding adhesives) should be determined in accordance with appropriate standards, such as corresponding ISO technical standards.

6 Structural analysis

Structural analysis of concrete structures with FRP materials should consist of the determination of structural response for the examination of limit states such as ultimate limit states and serviceability limit states. In general, structural analysis methodologies specified in ISO 19338 for structural concrete with traditional reinforcing materials may be applied for concrete structures with FRP materials.

Structural analysis of concrete structures with FRP materials should take into account the linear elastic material properties of FRP and the possible debonding failure between the FRP and concrete, which