SLOVENSKI STANDARD
kSIST-TS FprCEN/TS 19101:2022

01-junij-2022

Projektiranje kompozitnih konstrukcij iz vlaken in polimerov

Design of fibre-polymer composite structures

Bemessung von Tragwerken aus Faserverbund-Kunststoffen

Ta slovenski standard je istoveten z: **FprCEN/TS 19101**

ICS:

91.010.30	Tehnični vidiki	Technical aspects
91.080.99	Druge konstrukcije	Other structures

kSIST-TS FprCEN/TS 19101:2022 **en,fr,de**

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

TECHNISCHE SPEZIFIKATION

FINAL DRAFT FprCEN/TS 19101

April 2022

ICS 91.010.30

English Version

Design of fibre-polymer composite structures

Bemessung von Tragwerken aus Faserverbund-Kunststoffen

This draft Technical Specification is submitted to CEN members for Vote. It has been drawn up by the Technical Committee CEN/TC 250.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. FprCEN/TS 19101:2022 E

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European foreword

This document (FprCEN/TS 19101:2022) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This document is currently submitted to the Vote on TS.

This document has been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

This document has been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by this document.

Introduction

0.1 Introduction to FprCEN/TS 19101

This document for the design of fibre-polymer composite structures, which was prepared in line with the Eurocodes, is intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE 1 Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

NOTE 2 Fibre-polymer composites are also commonly referred to as fibre-reinforced polymers (FRP) or as composites.

0.2 Verbal forms used in this Technical Specification

The verb “shall" expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may" expresses a course of action permissible within the limits of the Eurocodes.

The verb “can" expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.3 National Annex to FprCEN/TS 19101

This Technical Specification gives values within notes indicating where national choices can be made. Therefore, a national document implementing FprCEN/TS 19101 can have a National Annex containing all Nationally Determined Parameters to be used for the assessment of buildings and civil engineering works in the relevant country.

When not given in the National Annex, the national choice will be the default choice specified in the relevant Technical Specification.

The national choice can be specified by a relevant authority.

When no choice is given in the Technical Specification, in the National Annex, or by a relevant authority, the national choice can be agreed for a specific project by appropriate parties.

National choice is allowed in FprCEN/TS 19101 through the following clauses:

4.3.1.2(4), NOTE 2	4.4.6(1), NOTE	4.4.6(2), NOTE	4.4.6(3), NOTE
4.4.7.1(2), NOTE	4.4.7.1(3), NOTE	8.5(2), NOTE 4	10.3(1), NOTE 1
12.4.5.1(1), NOTE 1	D4.5(1), NOTE		

National choice is allowed in FprCEN/TS 19101 on the application of the following informative annexes:

Annex A	Annex B	Annex E

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of FprCEN/TS 19101

(1) This document applies to the design of buildings, bridges and other civil engineering structures in fibre-polymer composite materials, including permanent and temporary structures. It complies with the principles and requirements for the safety, serviceability and durability of structures, the basis of their design and verification that are given in EN 1990.

NOTE In this document, fibre-polymer composite materials are referred to as composite materials or as composites.

(2) This document is only concerned with the requirements for resistance, serviceability, durability and fire resistance of composite structures.

NOTE 1 Specific requirements concerning seismic design are not considered.

NOTE 2 Other requirements, e.g. concerning thermal or acoustic insulation, are not considered.

(3) This document gives a general basis for the design of composite structures composed of (i) composite members, or (ii) combinations of composite members and members of other materials (hybrid-composite structures), and (iii) the joints between these members.

(4) This document applies to composite structures in which the values of material temperature in members, joints and components in service conditions are (i) higher than -40 °C and (ii) lower than T_g - 20 °C, where T_g is the glass transition temperature of composite, core and adhesive materials, defined according to 5.1(1).

NOTE 1 Composite structures have a temperature-dependent behaviour. The temperature-dependence of the properties of composite, core and adhesive materials is considered through a conversion factor for temperature, η_c, as defined in 4.4.7.2, which depends on the T_g and the maximum material temperature in service conditions (T_s).

NOTE 2 5.1(1) defines requirements for the T_g of composite, core and adhesive materials as a function of the T_s.

(5) This document applies to:

(i) composite members, i.e. profiles and sandwich panels, and

(ii) bolted, bonded and hybrid joints and their connections.

NOTE 1 Profiles and sandwich panels can be applied in structural systems such as beams, columns, frames, trusses, slabs, plates and shells.

NOTE 2 Sandwich panels include homogenous core and web-core panels. In web-core panels, the cells between webs can be filled (e.g. with foam) or remain empty (e.g. panels from pultruded profiles).

NOTE 3 This document does not apply to sandwich panels made of metallic face sheets.

NOTE 4 Built-up members can result from the assembly of two or more profiles, through bolting and/or adhesive bonding.

NOTE 5 The main manufacturing processes of composite members include pultrusion, filament winding, hand layup, resin transfer moulding (RTM), resin infusion moulding (RIM), vacuum-assisted resin transfer moulding (VARTM).

NOTE 6 This document does not apply to composite cables or special types of civil engineering works (e.g. pressure vessels, tanks or chemical storage containers).

(6) This document applies to:

(i) the composite components of composite members, i.e. composite plies, composite laminates, sandwich cores and plates or profiles, and

(ii) the components of joints or their connections, i.e. connection plates or profiles (e.g. cleats), bolts, and adhesive layers.

NOTE 1 Composite components are composed of composite materials (i.e. fibres and matrix resins) and core materials. Components of joints and their connections are also composed of composite, steel or adhesive materials.

NOTE 2 The fibre architecture of composite components can comprise a single type of fibres or a hybrid of two or more types of fibres.

NOTE 3 This document does not apply to composite components used for internal reinforcement of concrete structures (composite rebars) or strengthening of existing structures (composite rebars, strips or sheets).

(7) This document applies to composite materials, comprising:

(i) glass, carbon, basalt or aramid fibres, and

(ii) a matrix based on unsaturated polyester, vinylester, epoxy or phenolic thermoset resins.

NOTE This document does not apply to composite materials comprising a matrix based on thermoplastic resins.

(8) This document applies to the core materials (i) polymeric foams, and (ii) balsa wood.

NOTE 1 The core of sandwich panels can be reinforced by composite webs and inserts.

NOTE 2 This document does not apply to honeycomb cores.

(9) This document applies to thermoset adhesives, including epoxy, polyurethane, and acrylic resins.

NOTE This document does not apply to thermoplastic adhesives.

(10) This document applies to other types of fibres, thermoset resins, homogeneous cores and thermoset adhesives than those specified in 1.1(6)-(9), provided that their mechanical and physical properties are obtained from appropriate testing according to Clause 5, and that they are in line with the other relevant clauses of this document.

1.2 Assumptions

(1) The assumptions of EN 1990 apply to this document.

(2) This document is intended to be used in conjunction with EN 1990, EN 1991 (all parts), EN 1997 (all parts), EN 1998 (all parts), ENs, EADs and ETAs for construction products relevant to composite structures.

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.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in 'should' clauses), permissions ('may' clauses), possibilities ('can' clauses), and in notes.

prEN 1990:2021, *Basis of structural and geotechnical design*

EN 1991 (all parts), *Eurocode 1: Actions on structures*

prEN 1991-1-2:2021, *Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire*

EN 1993-1-4, *Eurocode 3: Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels*

prEN 1993-1-8:2021, *Eurocode 3: Design of steel structures – Part 1-8: Design of joints*

EN 1997 (all parts), *Eurocode 7: Geotechnical design*

EN 1998 (all parts), *Eurocode 8: Design of structures for earthquake resistance*

EN 13706-1, *Reinforced plastics composites – Specifications for pultruded profiles – Part 1: Designation*

EN 13706-2:2002, *Reinforced plastics composites – Specifications for pultruded profiles – Part 2: Methods of test and general requirements*

EN 13706-3, *Reinforced plastics composites – Specifications for pultruded profiles – Part 3: Specific requirements*

EN 16245 (all parts), *Fibre-reinforced plastic composites - Declaration of raw material characteristics*

ISO 6721-11, *Plastics — Determination of dynamic mechanical properties — Part 11: Glass transition temperature*

3 Terms, definitions, symbols and abbreviations

For the purposes of this document, the terms and definitions given in EN 1990 and the following terms, definitions, symbols and abbreviations apply.

3.1 Terms and definitions

3.1.1 Terms relating to constituent materials

3.1.1.1

accelerator

substance used in small proportions that accelerates the chemical reaction between the polymer resin system and the curing agent

3.1.1.2

additive

specialist chemical substance that is added to the polymer resin to impart specific matrix properties, such as removal from processing mould, flame retardancy and UV protection; known also as modifier

3.1.1.3

bi-directional ply

ply with all the continuous fibres aligned in two orientations

3.1.1.4

chopped strand mat

CSM

non-woven mat with short strands cut (approximately 50 mm long) from continuous fibre (or filament) strands and fairly evenly distributed and randomly oriented in a swirled pattern within the plane of the mat; the mat is held together by a binder

3.1.1.5

composite material

material composed of layers of rovings, fabrics, and mats, embedded in a polymer matrix

3.1.1.6

continuous fibre mat

CFM

non-woven mat with yarns or strands (of continuous fibres) fairly evenly distributed and randomly oriented in a swirled pattern within the plane of the mat; the mat is held together by a binder

3.1.1.7

core

central part of a sandwich panel to which top and bottom composite face sheets are attached

3.1.1.8

fibre

general term for a material in a filamentary form

3.1.1.9

filler

relatively inert substance added to the polymer resin to alter its physical, mechanical, thermal, electrical or other properties (e.g. shrinkage or flammability), or to lower cost

3.1.1.10

gel coat

thin layer of unreinforced quick-setting resin, sometimes containing a colorant, applied on the outer surface of a composite component to improve the surface properties

3.1.1.11

mat ply

ply comprising randomly oriented chopped or swirled continuous fibres loosely held together with a binder

3.1.1.12

non-woven fabric

textile structure produced by bonding or interlocking of continuous fibres, or both, accomplished by mechanical, chemical, thermal or solvent means, and combinations thereof

3.1.1.13

ply

single layer (or lamina) in a laminate with a number of individual layers of fibres

3.1.1.14

resin

solid, semisolid or pseudosolid organic material that has an indefinite and often high relative molecular mass, exhibits a tendency to flow when subjected to stress, and usually has a softening or melting range

3.1.1.15

roving

collection of parallel strands (assembled roving) or parallel continuous filaments (direct roving) assembled without intentional twist

3.1.1.16

sizing

coating applied to fibres during their manufacture to improve handling and fibre-matrix adhesion/compatibility, protect from water absorption and abrasion, lubricate the fibres and reduce static electricity

3.1.1.17

surface veil

very thin mat, usually 0,18 mm to 0,51 mm thick, of highly filamentized non-reinforcing fibres

Note 1 to entry: Usually present in pultruded composite materials to enhance the quality of the surface finish, to block out the fibre pattern of the underlying fibre layers and to add ultraviolet protection and a moisture diffusion barrier.

3.1.1.18

tape

prepreg of finite width consisting of resin impregnated unidirectional fibres

3.1.1.19

thermoset

class of polymers that, when cured using heat, chemical, or other means, changes into a substantially infusible and insoluble material, through the formation of cross-links (primary bonds) between the molecular chains

3.1.1.20

tow

large number of filaments collected into a loose strand or assemblage substantially without twist; commonly used in referring to carbon fibres; typically designated by a number followed by K, meaning multiplication by 1 000 (e.g. a 12K tow has 12 000 filaments)

3.1.1.21

unidirectional ply

ply with all the continuous fibres aligned in a single orientation

3.1.1.22

woven fabric

generic architecture consisting of interlaced yarns or fibres, usually a planar structure; the warp direction of the woven fabric is taken to be the longitudinal direction, which is the direction of the principal load action

3.1.1.23

woven roving

woven fabric formed by the weaving of rovings

3.1.2 Terms relating to manufacturing

3.1.2.1

cure

process of hardening of a thermosetting polymer resin (by cross-linking of the molecular structure); may be accomplished by addition of curing agents, with or without catalyst, and with or without heat energy

3.1.2.2

cure temperature

temperature profile to which the composite material or adhesive is subjected to during the curing process

3.1.2.3

fibre content

quantity of fibres in the composite material; usually expressed as the percentage of volume or weight fraction in the composite material

3.1.2.4

filament winding

automated composite manufacturing process in which continuous filaments (or tapes) are covered with resin and wound onto a rotating mandrel in a predetermined pattern design under controlled tension

3.1.2.5

gel time

period of time from a pre-determined starting point to the onset of gelation time (gel point) as defined by a specific test method

3.1.2.6

hand layup

composite manufacturing process in which a polymer resin and the fibre layers are applied manually either to an open mould or to a working surface in a number of successive layers

3.1.2.7

layup

fabrication process involving the stacking of successive plies (also referred to as laminae or layers)

3.1.2.8

post-cure

additional elevated temperature cure of the matrix usually without pressure

Note 1 to entry: For certain resins, complete cure is attained only by exposure of the polymer matrix to higher temperatures.

3.1.2.9

pultrusion

automated, continuous closed mould manufacturing process for thin-walled open and closed composite shapes (or profiles or sections), having constant cross-sectional area in the direction of pultrusion

3.1.2.10

resin infusion moulding

RIM

composite manufacturing process in which a catalysed polymer resin is infused into a closed mould already containing the preform for the component, with application of vacuum

3.1.2.11

resin transfer moulding

RTM

composite manufacturing process in which a catalysed polymer resin is injected into a closed mould already containing the preform for the component

3.1.2.12

vacuum-assisted resin transfer moulding

VARTM

composite manufacturing process in which a catalysed polymer resin is introduced into a closed mould already containing the preform for the component, with simultaneous application of vacuum to assist in resin flow