SLOVENSKI STANDARD
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Preskusne metode za ugotavljanje prispevka k požarni odpornosti konstrukcijskih elementov - 11. del: Zaščita trdnih jeklenih palic v napetosti na podlagi požarnih preskusov z mehansko obremenitvijo

Test methods for determining the contribution to the fire resistance of structural members - Part 11: Applied protection to solid steel bars in tension based on mechanically loaded fire tests

Prüfverfahren zur Bestimmung des Beitrages zum Feuerwiderstand von tragenden Bauteilen - Teil 11: Brandschutzmaßnahmen für Stahl-Vollstäbe unter Zugbeanspruchung basierend auf einer Brandprüfung unter mechanischer Belastung

Méthodes d'essai pour la détermination de la contribution de la résistance au feu d'éléments de construction - Partie 11 : Protection appliquée aux barres en acier pleines précontraintes sur la base d'essais au feu soumis à une charge mécanique

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Test methods for determining the contribution to the fire resistance of structural members - Part 11: Applied protection to solid steel bars in tension based on mechanically loaded fire tests

Méthodes d'essai pour la détermination de la contribution de la résistance au feu d'éléments de construction - Partie 11 : Protection appliquée aux barres en acier pleines précontraintes sur la base d'essais au feu soumis à une charge mécanique

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This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 127.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (prEN 13381-11:2024) has been prepared by Working Group 1 'Structural and separating elements' under Technical Committee CEN/TC 127 "Fire safety in buildings", the secretariat of which is held by BSI.

This document is currently submitted to the CEN Enquiry.

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

This document is one of a series of standards for evaluating the contribution to the fire resistance of structural members by applied fire protection materials. Other parts of this series are:

Part 1: Horizontal protective members.

Part 2: Vertical protective members.

Part 3: Applied protection to concrete members.

Part 4: Applied passive protection to steel members.

Part 5: Applied protection to concrete/profile sheet steel and composite members.

Part 6: Applied protection to concrete filled hollow steel columns.

Part 7: Applied protection to timber members.

Part 8: Applied reactive protection to steel members.

Part 9: Applied fire protection systems to steel beams with web openings.

Part 10: Applied protection to solid steel bar in tension.

Introduction

The evaluation of a system's capability to provide fire protection performance to beams and/or columns with I- or H-section as well as hollow section is undertaken by test and assessment procedures detailed in EN 13381-8 for reactive (intumescent) fire protection systems. The scope of the above standard excludes the assessment of solid steel bars used as tension members.

In general, it is not possible to use the results of fire protection systems tested according to EN 13381-8 on beams or columns with open or closed profile to steel tension bars with solid section. This has several reasons:

a) the profiles used for steel bars are usually much slenderer than the profiles used for beams or columns. Consequently, to achieve the same fire resistance usually higher thicknesses of the reactive fire protection system are required;

b) due to the different profile shape, there is an altered foaming and cracking behaviour of reactive fire protection systems. On the predominantly flat surfaces of a beam with open profile, reactive fire protection systems behave differently than on highly convex curved surface of steel bars with circular solid section;

c) because the tensile stresses in a steel bar are equal along the entire bar length and within the cross-section, the failure occurs at the position, where the highest steel temperature is present. Therefore, tensile bars are vulnerable to local defects, e.g. cracks or ununiform foam thicknesses of reactive fire protection systems. Furthermore, beams have the possibility of cross-sectional plasticisation. Due to the resulting stress redistribution and the activation of additional load capacity reserves, in fire tests beams suffer lower strains compared to a bar in pure tension. This is also clear from the fact that the tests of a steel bar usually end with the breakage. In mechanically loaded beam tests such a high strain is usually not achieved;

d) columns are not suitable for a comparison with steel bars, because the cross-sections are much bigger as well as the thermal and mechanical strains are acting in opposite direction;

e) in contrast to beams, which are generally used in a horizontal position, steel bars are used in different orientations. This may influence the thermal protection performance of the reactive fire protection system.

For reactive fire protection systems that have already been successfully tested and assessed according to EN 13381-8, the test standard EN 13381-10 offers under certain conditions the possibility to extend the scope of application to steel tension bars with solid sections. The fire tests in EN 13381-10 are based upon unloaded specimens. Because this approach contradicts to the German national safety level, where the fire resistance of structural members must be tested under mechanical load, an A-Deviation was granted, meaning that it is not possible to apply EN 13381-10 in Germany. In addition, recent research and testing on loaded and unloaded steel bars protected with reactive fire protection coatings has shown the need for mechanically loaded fire testing.

The following standard provides a test and assessment procedure to cover a reactive fire protection system's scope of application to solid circular or rectangular steel bars used as tension members based on mechanically loaded fire tests. The standard is a stand-alone test standard and does not require a successful completion of the test procedure according to EN 13381-8. The standard has been created to cover a testing and assessment procedure based primarily upon mechanically loaded fire tests. Across a range of solid circular and/or rectangular bars fire tests on mechanically loaded specimens are carried out. Unloaded specimens may be used to assess additional aspects, such as the influence of the bar orientation as well as smouldering fire behaviour. The assessment procedure described in this document aims to determine the reactive fire protection system's thermal protection performance.

The document does not apply to passive fire protection systems.

1 Scope

This document describes the test and assessment procedure for determining the contribution of reactive fire protection systems to the fire resistance of solid steel bars used as tension members, when exposed to the standard temperature/time curve specified in EN 1363-1. In special circumstances, where specified in National Building Regulations, there can be a need to subject reactive fire protection systems to a slow heating curve (smouldering fire) as defined in EN 1363-2. The corresponding test and assessment procedure are described in Annex E. The fire protection performance is determined by testing mechanically loaded steel bars in horizontal orientation. Information regarding the testing of additional unloaded specimens is given to assess the influence of the bar orientation and smouldering fire behaviour.

The principles of the testing and assessment procedure can also be applied for other section shapes such as angles, channels and flats. This document does not include steel bars used as reinforcement in concrete construction.

The document is applicable to steel bars up to a maximum diameter of 130 mm. In the case of rectangular bars, the maximum edge length is limited to 130 mm with a maximum aspect ratio of 2:1 against the shorter edge length.

The test programme and the assessment are designed to cover:

— a range of valid fire protection classification periods;

— a range of thickness of the applied reactive fire protection system;

— a range of steel bar dimensions and profiles;

— a range of specified design temperatures;

— a range of load utilization factors in case of fire;

— a range of bar orientation.

This document also provides the assessment procedure, which prescribes how the analysis of the test data is made and gives guidance on the procedures by which interpolation is undertaken. The assessment procedure is used to establish:

a) on the basis of data derived from mechanically loaded testing steel bar, any practical constraints on the use of the reactive fire protection system under fire test conditions (the physical performance);

b) on the basis of the temperature data derived from testing steel bar the thermal properties of the reactive fire protection system (the thermal performance).

The limits of applicability of the results of the assessment arising from the fire test are defined together with permitted direct application of the results to different steel types and sizes over the range of thicknesses of the applied reactive fire protection system tested.

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.

EAD 350402-00-1106, *Reactive coatings for fire protection of steel elements*

EN 1363-1:2020, *Fire resistance tests — Part 1: General requirements*

EN 1363-2, *Fire resistance tests — Part 2: Alternative and additional procedures*

EN 10025-1, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1)*

EN 10204, *Metallic products — Types of inspection documents*

EN ISO 13943, *Fire safety — Vocabulary*

EN 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 7500-1)*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1363-1, EN ISO 13943 and ISO 8421-2, and the following 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
steel bar
element of building construction, which is loadbearing and fabricated from steel. It has a solid circular or rectangular (including square) cross-section composed entirely of steel with a consistent cross-sectional size throughout its length

3.1.2
reactive fire protection material
reactive materials which are specifically formulated to provide a chemical reaction upon heating such that their physical form changes and in doing so provide fire protection by thermal insulative and cooling effects

3.1.3
fire protection system
fire protection material together with any supporting system including mesh reinforcement and a specified primer and top coat if applicable

3.1.4
fire protection
protection afforded to the steel member by the reactive fire protection system such that the temperature of the steel member is limited throughout the period of exposure to fire

3.1.5
test specimen
steel bar plus the reactive fire protection system under test

3.1.6
fire protection thickness
mean dry film thickness of the reactive fire protection material excluding primer and top coat

3.1.7
stickability
ability of a reactive fire protection system to remain sufficiently coherent and in position for a well-defined range of deformations, furnace and steel temperatures, such that its ability to provide fire protection is not significantly impaired

3.1.8
maximum steel temperature
the highest average temperature recorded at two measuring stations nearest the rupture point

3.1.9
section factor
ratio of the fire exposed outer perimeter area of the steel bar per unit length, to its cross-sectional volume per unit length

3.1.10
mechanical load
axial tensile force applied to the mechanically loaded specimen during the fire test (see 6.4)

3.1.11
load utilisation in case of fire
ratio of mechanical load to the tensile load carrying capacity of steel bar in case of fire (see 6.4)

3.1.12
test programme
describes the intended scope of application (see Clause 5)

3.1.13
test set
part of the test programme and consists of a group of mechanically loaded specimens (template see 5.6)

3.1.14
design steel bar temperature
temperature of a steel bar, which shall be used for the assessment of the physical and thermal performance

3.1.15
deformation steel bar temperature
temperature of a steel bar, which shall be used by the structural engineer to check the total deformation of the steel bar and the entire steel construction at elevated temperature

3.2 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

Symbol	Unit	Description
α	K^{-1}	thermal expansion coefficient
A_m/V	m^{-1}	Section factor of the unprotected steel section
$A_{section}$	mm^2	Cross-sectional area of the steel section
b	mm	Width of the rectangular solid steel section
D	mm	Diameter of the circular solid steel section
d_p	mm	Thickness of reactive fire protection system
d_{min}	mm	minimum protection thickness of the loaded or tall section (according to EN 13381-8)
d_{max}	mm	maximum protection thickness of the loaded or tall section (according to EN 13381-8)
D_{small}	mm	Diameter of the smaller tested steel bar from the fire test
D_{large}	mm	Diameter of the larger tested steel bar from the fire test
D_{select}	mm	Diameter of steel bar for which appropriate dry film thickness is calculated
DFT_{mean}	mm	Mean value of all thickness measurements of the fire protection material
DFT_{small}	mm	Dry film thickness of the smaller tested steel bar from the fire test
DFT_{large}	mm	Dry film thickness of the larger tested steel bar from the fire test
DFT_{ref}	Mm	Dry film thickness of the unloaded steel bar used as reference specimen
DFT_K	mm	DFT_{mean} of the unloaded steel bar for which the correction time ($t_{corection,k,i}$) is calculated
$\dot{e}$	min^{-1}	Strain rate of steel
F_{load}	kN	The mechanical tensile load applied to the specimen
$f_{y,20°C}$	N/mm^2	Yield strength at room temperature
$f_{p0.2,20°C}$	N/mm^2	0,2 % proof stress at room temperature
h	mm	Height of the rectangular steel section
L_F	mm	Fire exposed length of the mechanically loaded specimen
L_G	mm	Total length of the mechanically loaded specimen
L_U	mm	Total length of unloaded steel bar
r	mm	Radius of the circular solid steel section

s	mm	Cross-sectional dimension of the specimen
θ_i	°C	Design steel temperature for the thermal and physical assessment
θ_{def}	°C	Steel deformation temperature for the check of the total deformation of the steel bar and the entire steel construction at elevated temperature
θ_s	°C	Maximum steel temperature at time t_i
$\theta_{rupture}$	°C	Steel temperature when the rupture occurred
θ_{select}	°C	Selected design temperature value for which the dry film thickness will be calculated
$\theta_{average,unload,i}$	°C	Average temperature of unloaded steel bar for different orientation
$\theta_{SH,average,unload,i}$	°C	Average temperature of unloaded specimen in different orientation for bars exposed to slow heating (SH) temperature/time curve
$\Delta\theta_k$	°C	Temperature difference between steel bars with different orientation
t	min	Fire performance period
t_F	min	Fire resistance time
t_C	min	The time when the load-bearing capacity (t_C) is reached
$t_{C,i}$	min	Time for which the load utilisation factor in case of fire is calculated for interpolation purposes
$t_{correction,k,i}$	min	Corrected time, when unloaded steel bar reached design temperature θ_i
$t_{k,i}$	min	Time for the reference section to reach the design temperature
$t_{rupture}$	min	Time when the steel bar rupture occurred
$\Delta T_{unload,i}$	°C	Temperature difference between unloaded steel bars with different orientations
$\Delta T_{load,k}$	°C	Temperature difference between loaded steel bars with different orientations
U	mm	Deformation of the steel bar including longitudinal elongation
dU/dt	mm/min	Rate of deformation
$\Delta dU/dt_{limit}$	mm/min	Limit value of the rate of deformation of the mechanically loaded specimen
μ_0	–	Load utilisation factor at ambient temperature
μ_{fi}	–	Load utilisation factor in case of fire
$\mu_{fi,max}$	–	Upper limit of load utilisation factor in case of fire
$\mu_{fi,min}$	–	Lower limit of load utilisation factor in case of fire